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Kansas City, MO

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16. ABSTRACT

This inspection guide has been written and organized for use by state and local enforcement field inspectors and entry-level engineers whose familiarity with foundry operations may be limited. It describes ferrous foundry processes and emissions control systems. It explains in layman's terms foundry emission problems and causes. It details step-by-step inspection procedures for process and control equipment, and is supplemented by inspection checklists. Health and safety guidelines for foundry inspectors are also listed.

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U.S. ENVIRONMENTAL PROTECTION AGENCY
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PREFACE

Midwest Research Institute (MRI) has prepared this Ferrous Foundry Inspection Guide for the U.S. Environmental Protection Agency, Division of Stationary Source Enforcement (EPA-DSSE) under EPA Contract No. 68-01-6314. Mr. Robert L. King of EPA-DSSE was task manager for this project.

This project was conducted by Mr. Raj Shah, Task Leader, under the supervision of Mr. Andrew Trenholm, Head, Environmental Control Systems Section.

MRI would like to express its appreciation to the many individuals in federal, state, and local air pollution agencies and the foundry industry who contributed to the study.

Approved for:

MIDWEST RESEARCH INSTITUTE

MP Schrag

M. P. Schrag, Director
Environmental Systems Department

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SECTION 1.0

INTRODUCTION

The success of a field enforcement program ultimately depends on the field inspectors and the results of their inspections. The importance of following inspection procedures closely cannot be overly emphasized. Air pollution control agencies with adequate enforcement powers, but inadequate inspection and enforcement procedures, may lose some of these powers as a result of adverse court decisions. The ability to identify, describe, and evaluate air pollution emissions and the factors contributing to their formation is fundamental to inspection procedures.

The field inspectors are involved in field surveillance and monitoring of a variety of sources for continuing compliance. A "continuing compliance inspection" is an inspection of sources which have previously proved initial compliance with the regulations in that they have installed the necessary air pollution control equipment and/or modified their process(s) to be able to meet required emission limits on a continuing, long term basis. Most agencies perform a continuing compliance inspection once or twice a year depending upon their resources or any complaints received.

This inspection guide designed by the Environmental Protection Agency (EPA) has been written and organized for use by state and local enforcement field inspectors and entry-level engineers whose familiarity with foundry operations may be limited. The guide can be useful both as a training manual in foundry operations and as a guidebook during field inspections.

A main objective of this guide is to present relevant information about foundries in layman's language. Thus, we have purposely not included technical discussions on subjects such as stack testing, emission factors, effects of control and process equipment variables on emissions, engineering calculations, etc. For this reason, the guide will be considered "basic" by those senior engineering staff with experience in foundry operations. Such staff should consult the extensive references listed in the bibliography for information on unique or complex foundry problems. More experienced staff may prefer to start this guide with Chapter 4. Also, it is expected that the users of this guide, field inspectors, will seek out senior engineering staff for guidance when a serious or potentially serious emission problem is discovered. By using this guide, field inspectors will become competent problem locators.

This guide presents an overview of foundry operations and describes typical emission problems in a foundry. It explains causes of the problems and possible corrective measures. It also describes types of control equipment used in foundry operations and typical problems with control equipment.

Throughout this guide are terms used in the ferrous foundry industry. A glossary of these terms is contained in Appendix A.

Appendix B contains process and control equipment checklists that have been prepared for use during inspections to assure continued compliance of foundry operations. In using these checklists, it is assumed that basic data on the processes already exist in the agency files and that the foundry being inspected has an operating permit showing initial compliance with the regulations.

SECTION 2.0

FERROUS FOUNDRY PROCESSES AND EMISSIONS CONTROL SYSTEMS

A ferrous foundry converts scrap iron and steel to usable cast iron and cast steel products. The field inspector with a basic understanding of foundries is able to identify compliance problems. In addition, information from past surveys suggests that the inspector who demonstrates such an understanding can expect more cooperation from foundry personnel.

There is no "typical" ferrous foundry. Ferrous foundries vary with respect to type and size of casting produced, quantity of metal melted daily, choice of equipment and materials for a particular function, and the degree of mechanization of different processes. Therefore, this chapter cannot provide a walkthrough inspection guide for a given foundry, but it does provide enough information about the different operations of a foundry that the inspector can direct an inspection tour.

Ferrous foundries process various grades of iron and steel scrap, and sometimes pig iron, to produce cast products from one or more of the following ferrous metals: gray iron, ductile (or nodular) iron, malleable (sometimes called white) iron, and steel. These various types of ferrous metals are differentiated by their chemical compositions as shown in Table 2-1. Pig iron is different in comparison to other ferrous metals, as it is manufactured by the reduction of iron ore smelted in a blast furnace with coke and limestone. Generally, pig iron is produced in large steel mills and is used directly in the manufacture of steel and steel products. In some cases, it is used to produce ferrous castings with or without refining or alloying treatments. Other ferrous metals are generally made from the mixtures of steel and ferrous scrap with or without various alloying agents. The type of metal used will depend upon what type of final casting is required.

Most foundries have five basic process areas: (a) the pattern shop; (b) the core and mold making area; (c) the melt shop, which includes both melting and casting; (d) the cleaning and finishing area; and (e) the sand handling system. In addition, each foundry has raw material and waste handling and storage operations. The general flow system of a ferrous foundry is shown in Figure 2-1. The reader is reminded that these operations vary considerably from foundry to foundry.

TABLE 2-1. CHEMICAL COMPOSITION OF FERROUS CASTINGS[27,9]

Element	Gray iron (%)	Malleable iron (as white iron) (%)	Ductile iron[a] (%)	Steel (%)	Pig iron (%)
Carbon	2.5-4.0	1.8-3.6	3.0-4.0	< 2.0[b]	3.0-4.5
Silicon	1.0-3.0	0.5-1.9	1.4-2.0	0.2-0.8	0.5-4.0
Manganese	0.40-1.0	0.25-0.80	0.5-0.8	0.5-1.0	0.2-1.50
Sulfur	0.05-0.25	0.06-0.20	< 0.12	< 0.06	0.04-0.10
Phosphorus	0.05-1.0	0.06-0.18	< 0.15	< 0.05	0.1-2.5

[a] Also includes 0.01 to 1.0% Mg.

[b] Steels are further classified by carbon content as follows: low carbon - < 0.20%, medium carbon - 0.20-0.50%, high carbon - > 0.50%.

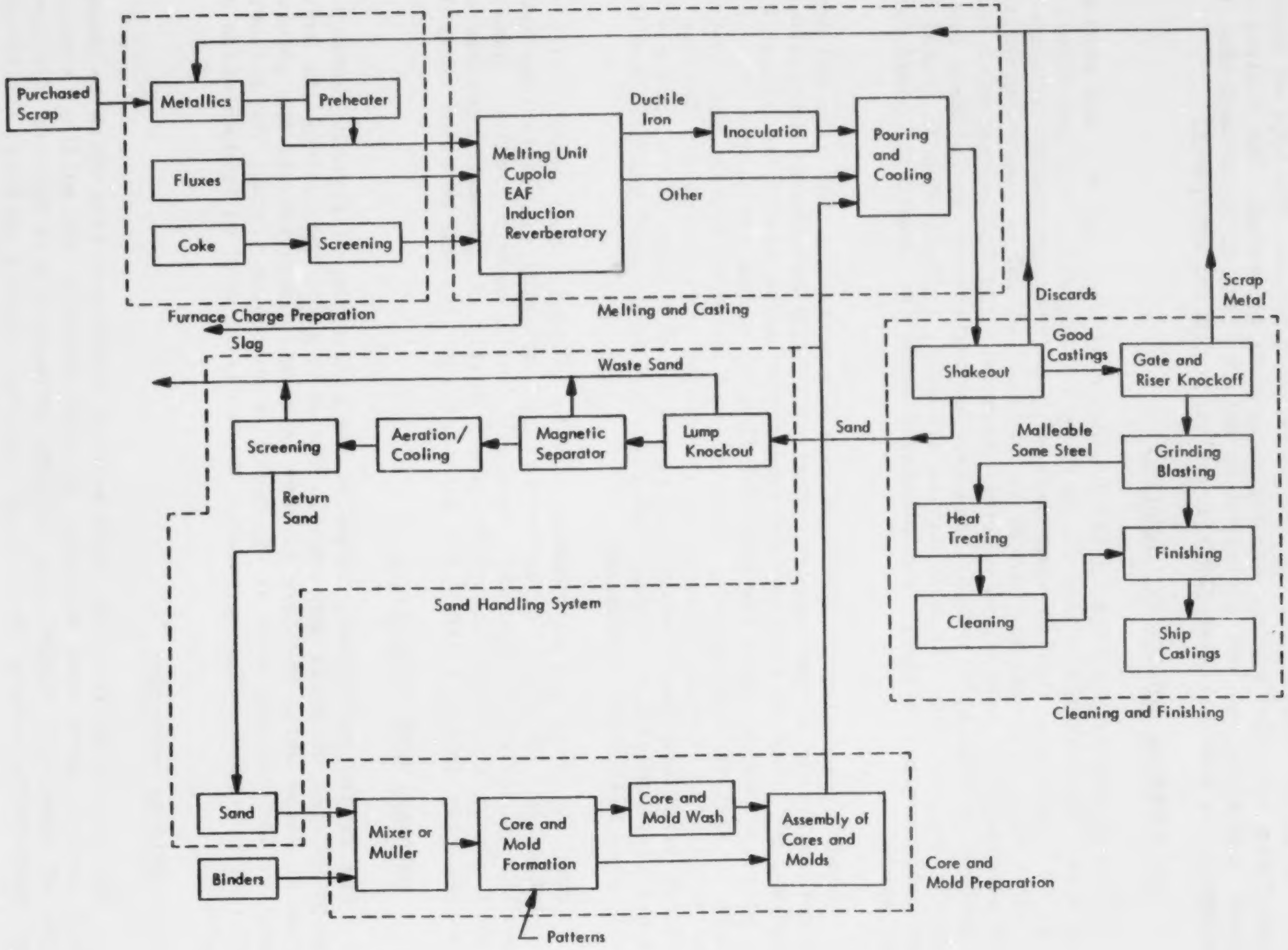

Purchased Scrap
Metallics
Preheater
Fluxes
Coke
Screening
Furnace Charge Preparation
Melting Unit Cupola EAF Induction Reverberatory
Ductile Iron
Other
Inoculation
Pouring and Cooling
Melting and Casting
Slag
Discards
Scrap Metal
Shakeout
Good Castings
Gate and Riser Knockoff
Malleable Some Steel
Grinding Blasting
Heat Treating
Cleaning
Finishing
Ship Castings
Cleaning and Finishing
Waste Sand
Sand
Screening
Aeration/ Cooling
Magnetic Separator
Lump Knockout
Return Sand
Sand Handling System
Sand
Binders
Mixer or Muller
Core and Mold Formation
Core and Mold Wash
Assembly of Cores and Molds
Core and Mold Preparation
Patterns

Figure 2-1. Flow diagram of ferrous foundry.

This chapter describes the unit operations, except pattern making, that are most often found within each of the operating areas. The pattern shop was excluded because industry and control agency personnel have not identified it as contributing to the air pollution problem. The type of control associated with the process equipment is also described. The control devices themselves are not described in detail since it is assumed that the inspector is familiar with the air pollution control equipment.

2.1 RAW MATERIAL STORAGE AND HANDLING

Raw materials are used in the foundry melt shop and core and mold making area. Raw materials used for melting include scrap iron and steel, borings and turnings, limited quantities of pig iron, and foundry returns for metallic content; coke for energy in the cupolas and in limited quantities for metallurgical control in electric furnaces; and fluxing material such as limestone, dolomite, fluorspar, and calcium carbonate. The primary raw materials used in core and mold making are sand, fillers such as cereal and sea coal, organic binders, and precoated sands for chemically bound cores and molds.

Handling and storage practices vary depending upon the size and degree of mechanization of the foundry. Most of the furnace charge materials are received by truck or rail and are transferred mechanically to storage bins or piles. In most cases the coke and fluxing agents are stored in covered areas to prevent degradation. Both covered and open storage are used for the metallics. Covered storage is preferable environmentally because it reduces windblown fugitive emissions, and cleaner materials ultimately reduce furnace emissions. Other than covering, no control measures are typically used with these operations.

Sand for core and mold making may be handled either mechanically or pneumatically. However, environmental and material considerations have resulted in increased pneumatic transport in the modern foundry. Sand is almost always stored in enclosed silos. Nearly all pneumatic systems are equipped with fabric filters for material recovery and emission control.

2.2 MOLD AND CORE PREPARATION

One of the preliminary steps in the production of ferrous casting is the production of molds and cores. The mold gives the casting its basic exterior shape while the core is used to form indentations or the internal shape of the casting, such as cylinders in an engine block. The following sections describe various processes which can be used to produce molds and cores.

2.2.1 Molding Processes

The foundry operator has many molding techniques from which to choose. These include green sand molding, dry sand molding, pit molding, various types of chemically bonded sand molding, permanent mold casting, die casting, investment casting, centrifugal casting, plaster molding, and ceramic molding.[1,2] This section discusses green sand molds, dry sand molds, and pit molds since these methods account for the vast majority of castings and have the greatest emission potential. Since chemically bonded sand molding processes and emissions are similar to coremaking processes, they are described in Section 2.2.2, Coremaking Process.

By far the greatest tonnage of castings is poured in green sand molds. Green sand molds are made with a moist sand, and the moisture is retained in the sand through the time when the metal is poured. The four steps in green sand molding are: (a) preparation of the pattern; (b) preparation of the sand (mulling); (c) making of the mold; and (d) core setting. The only step in the process which produces significant particulate emissions is mulling. Water, sand, and binding materials such as bentonite clay, sea coal, and cereal additives are mixed in a muller, examples of which are shown in Figures 2-2 and 2-3. Since the materials are wetted quickly during mulling, some potential for emissions occurs during the charging of materials, particularly binders, to the muller, but these emissions are well controlled in most mechanized operations. Mechanized molding machines are then used to form the mold in two halves, the cope or upper half and the drag or lower half. After both halves are formed, cores are placed in the mold and the cope and drag are fastened together. Examples of molding machines are shown in Figure 2-4.

Because of the moisture content of the sand, the emissions from molding are generally quite low, precluding the necessity for air pollution control equipment. The mullers are generally controlled by an exhaust ventilation system such as the one shown in Figure 2-3. The exhaust from the muller is vented to a fabric filter or low energy wet scrubber before discharge to the atmosphere.

Dry sand molds are used to produce steel castings or thick section castings of a large size and weight. Dry sand molds are prepared with sands and binders which do not require moisture. Additives include pitch, sodium silicate, gilsonite, cereal, molasses, dextrine, gluten, and resins. These additives are mixed with the sand in a muller and the mixture is formed into molds. The molds are then heated in an oven to produce strong, rigid mold walls. Controls are similar to those used in green sand mold production.

Pit molds, which are used to produce castings too large for a flask, may be made in a pit by a bedding-in method. The pattern is set in a pit in the position in which the casting is to be poured, and sand is rammed or tucked under and around the sides of the pattern. The cope for the complete mold may rest on the drag at or above floor level and may be bolted down to prevent runout at the parting plane. Many foundries have a concrete-lined pit equivalent to the size of the mold they customarily produce. The mold may be rammed up, striking off the surface to produce the desired shape. At times, when the design of the casting is such that a pattern cannot be drawn out of the mold the entire mold cavity may be constructed with cores.

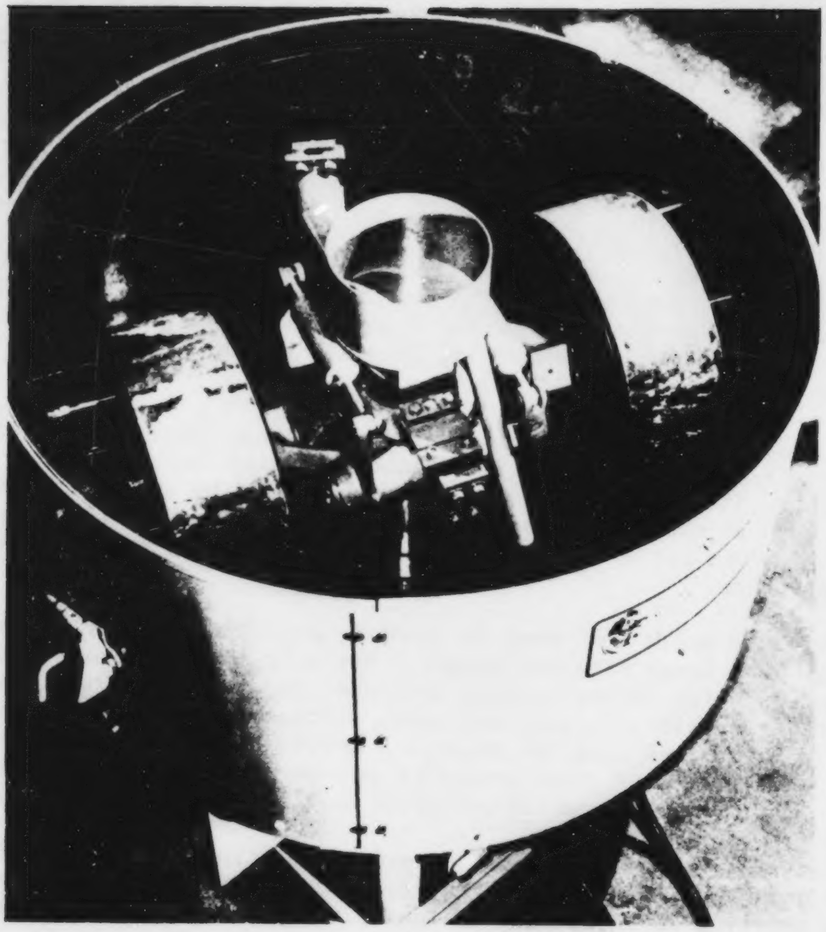
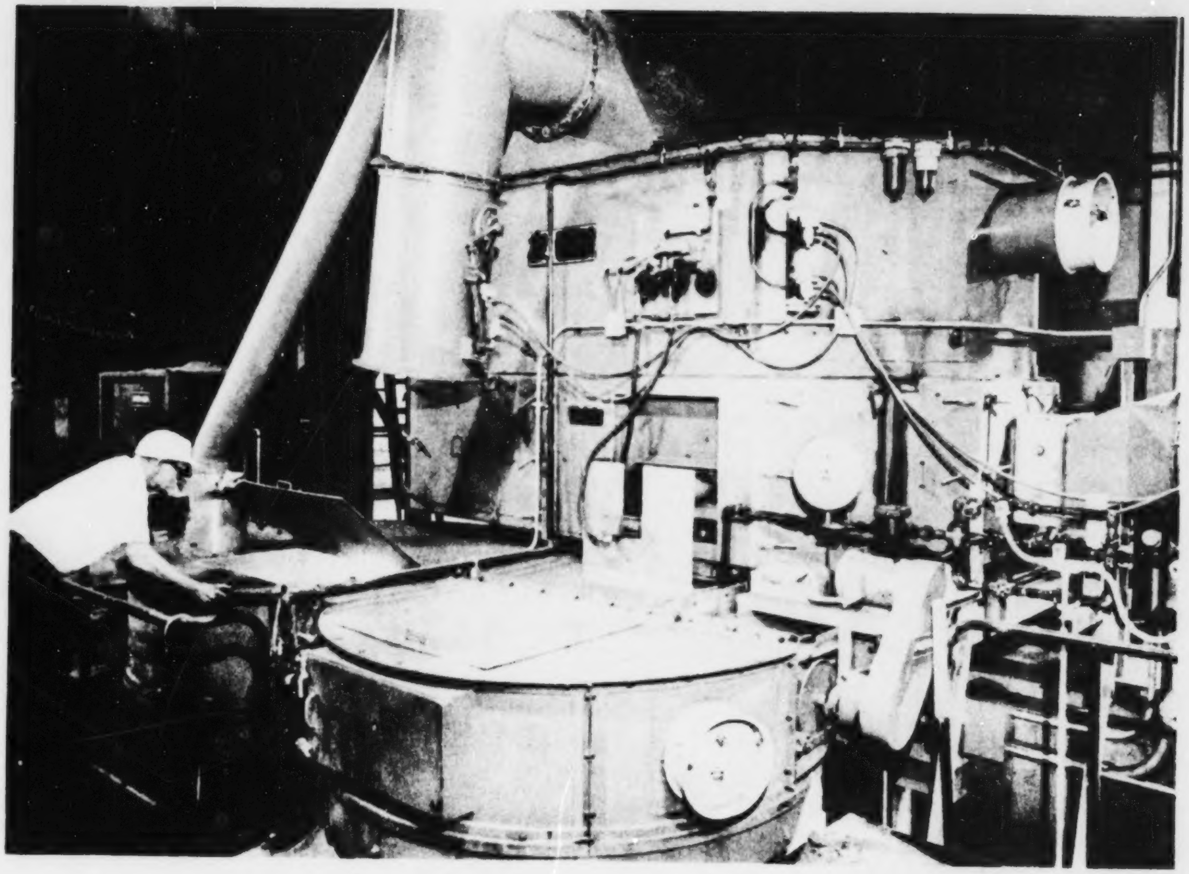


Figure 2-2. Typical muller for mixing molding sand (courtesy National Engineering Company).[2]



Reproduced from best available copy.

Figure 2-3. Modern continuous sand cooler rides piggyback on continuous figure-8 muller--can put out 70 tons/hr of prepared sand without a whisp of dust.[3]

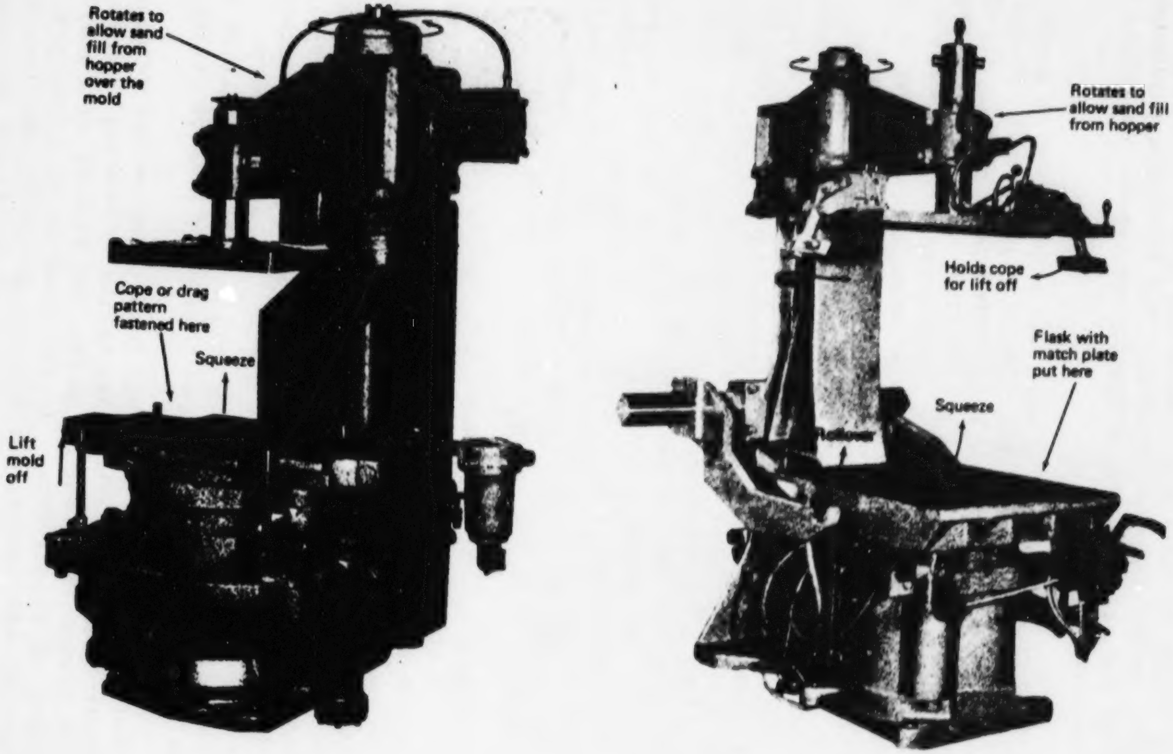

Rotates to allow sand fill from hopper over the mold
Cope or drag pattern fastened here
Squeeze
Lift mold off
Rotates to allow sand fill from hopper
Holds cope for lift off
Flask with match plate put here
Squeeze
Rollover

Figure 2-4. (a) A ram-jolt-squeeze-stripper mold-making machine; (b) a ram-jolt-squeeze-turnover-stripper mold-making machine. A complete mold is produced at each cycle of 3 to 5 min (The Osborn Manufacturing Company).[4]

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2.2.2 Coremaking Processes

Cores are prepared by mixing clean sand with one of several types of organic binders followed by a chemical or thermal setting process to form a hard, rigid core. There are five types of coremaking processes: oven bake, shell, hot box, cold box or gassed core, and no-bake. The level of usage of each process is shown in Table 2-2. Emissions from coremaking processes are primarily organic vapors from the binders. The following paragraphs briefly describe each of the processes and identify the organic emissions that can be expected from each process.

Oven-baked cores are formed in much the same manner as green sand and dry sand molds. After the oven-baked core is molded, it is placed on a flat core plate or formed core dryer and transferred to a gas- or oil-fired oven. In the oven the light oil fractions and moisture are driven off with acids, aldehydes, and photochemically active hydrocarbons.[5] All ovens are vented to the atmosphere, and some ovens have afterburners or chemical scrubbers to minimize organic emissions.

Shell coremaking or shell molding produces cores or molds having a thickness of 1/8 to 3/8 in. These are used in applications requiring great precision. Sand and approximately 5% thermosetting resin (usually having a phenol-formaldehyde base) may be dry-mixed in a muller.[6,7] The sands may also be prepared by cold, warm, or hot coating. This mix is then blown into a metal box housing the pattern plate which has been heated to a temperature of 350 to 700°F.[5] The binder within 1/8 to 3/8 in. of the pattern is melted and the material is turned into a dough-like substance. Excess sand is dumped off, and the shell is allowed to harden. The primary emissions from the process are carbon monoxide, formaldehydes, amines, ammonia, and phenols. A shell core machine with its exhaust system is shown in Figure 2-5.

Hot box binders are those resins that rapidly polymerize in the presence of acidic chemicals and heat to form a mold or core. The original hot box resins are developed by modifying urea-formaldehyde resins with the addition of 20 to 45% of furfuryl alcohol. This type of hot box resin is commonly referred to as furan resin. The furan resins are then modified with the addition of phenol to produce urea-phenol-formaldehyde hot box resins, referred to as phenolic resins or UPF resins. The UPF resins have a pungent odor, and adequate ventilation at the coremaking machines is required. More recently, urea-free phenol-formaldehyde-furfuryl alcohol binders have been developed. Eliminating urea from the formulation has rendered these resins less volatile and odorous than other hot box resins.[6]

A two-part polyurethane cold box binder system was developed about 1967 that required gassing rather than baking or heating to achieve a cure. Part I of the system is a phenolic resin, and Part II is a polyisocyanate. Both are dissolved in solvents. In the presence of a catalyst, triethylamine or dimethyl ethylamine, the hydroxy groups of the liquid phenolic resin combine with the isocyanate groups of the liquid polyisocyanate to form a solid urethane resin which serves as the sand binder. Following introduction of the catalyst into the cold box, air is used to sweep any remaining vapors through the core, after which the core is removed from the core box.

TABLE 2-2. PRINCIPAL ORGANIC CORE BINDERS IN USE IN THE COREMAKING PROCESSES

Coremaking process	Organic binder
Oven bake	1. Oleoresinous
	2. Urea-formaldehyde resins
	3. Phenol-formaldehyde resins
	4. Cereal binders
Heated core box	1. Phenol-formaldehyde novolaks
Shell	2. Furan resins (UFFA)
Hot box	3. Phenol resins (UPF)
	4. Phenol-modified resins
Gassed core (cold box)	1. Isocyanate
No-bake	1. Air set (oil-oxygen)
	2. Furan no-bake
	3. Oil no-bake
	4. Urethane (phenolic-isocyanate)

Source: Bates, C. E., and L. D. Scheel, "Processing Emissions and Occupational Health in the Ferrous Foundry Industry," American Industrial Hygiene Journal, August 1974.

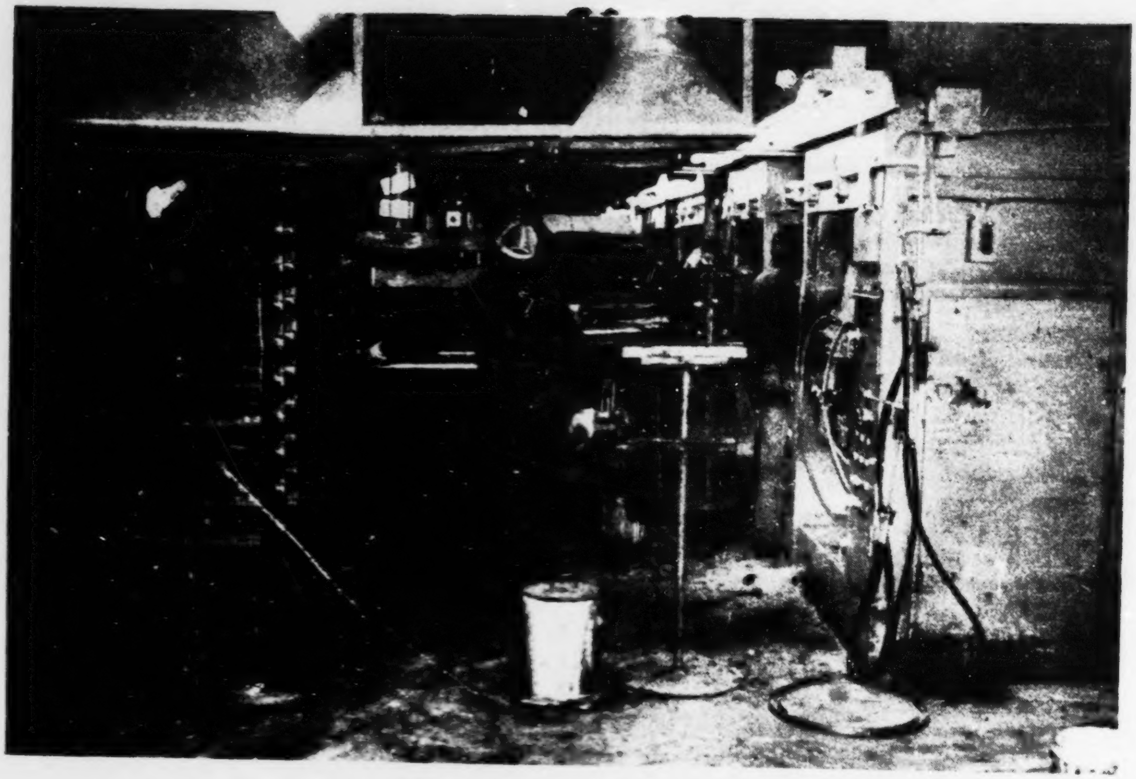


Figure 2-5(a). Shell molding and storage area with area ventilation.[8]

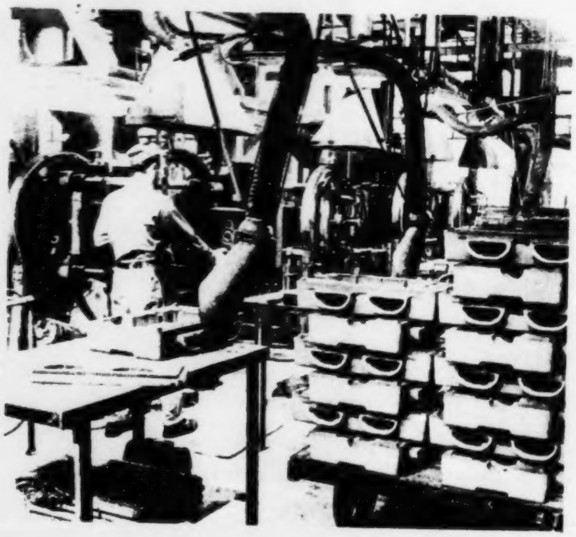


Figure 2-5(b). Typical exhaust system for shell molding.

The amine catalysts are volatile, flammable organic liquids, and their vapors present safety hazards.[6]

The no-bake binders represent modifications of the oleoresinous, urea-formaldehyde, phenol-formaldehyde, and polyurethane binder systems previously described, in which various chemicals are incorporated to produce polymerization in an unheated core box.[7]

For each of the coremaking methods, ventilation is needed, and afterburners or chemical scrubbers may be used to control organic emissions.

2.3 MELTING AND CASTING

The area of the foundry which has traditionally been of greatest concern to control agency personnel is the melt shop. Operations which may be found in the melting and casting department of a ferrous foundry include melting, superheating, or duplexing; inoculation, and pouring and cooling of the ferrous castings. The types of operation and specific equipment used in these operations vary from foundry to foundry depending on foundry size, type of metal cast, type and size of casting, number of castings produced, energy availability, and local environmental regulations. Figure 2-6 shows the materials flow commonly found in ferrous foundry melt shops.

The melt shop operations are briefly described in the following sections. The first section describes the three major types of furnaces used in ferrous foundries: the cupola, which is used for melting, and electric arc and electric induction furnaces, which are used for melting, duplexing, and holding molten metal. The second section describes the different methods used to inoculate ductile iron. The final section describes pouring and cooling operations.

2.3.1 Ferrous Foundry Furnaces

Almost all the metal used in ferrous foundries is melted in one of three furnaces. Cupolas account for about 75% of the ferrous foundry production, electric arc furnaces about 17%, and electric induction furnaces about 7%. The operations and controls for these furnaces are described below.

2.3.1.1 Cupola Furnace--

The cupola furnace is the principal melting unit in gray iron and ductile iron foundries. The cupola is an upright, cylinder-shaped vessel which uses the heat from the charged coke to melt iron. Three types of cupolas are illustrated in Figure 2-7. The cupola operation may be continuous. Metallics, coke, and fluxing agents are charged in layers near the top of the furnace, and the molten iron is tapped from the bottom. The cupola bottom consists of two hinged doors which are blocked closed during the operation but are opened after melting is completed to dump the remaining charge. Before melting is started, the doors are closed and the floor packed with 8 to 10 in. of sand to seal the cupola.

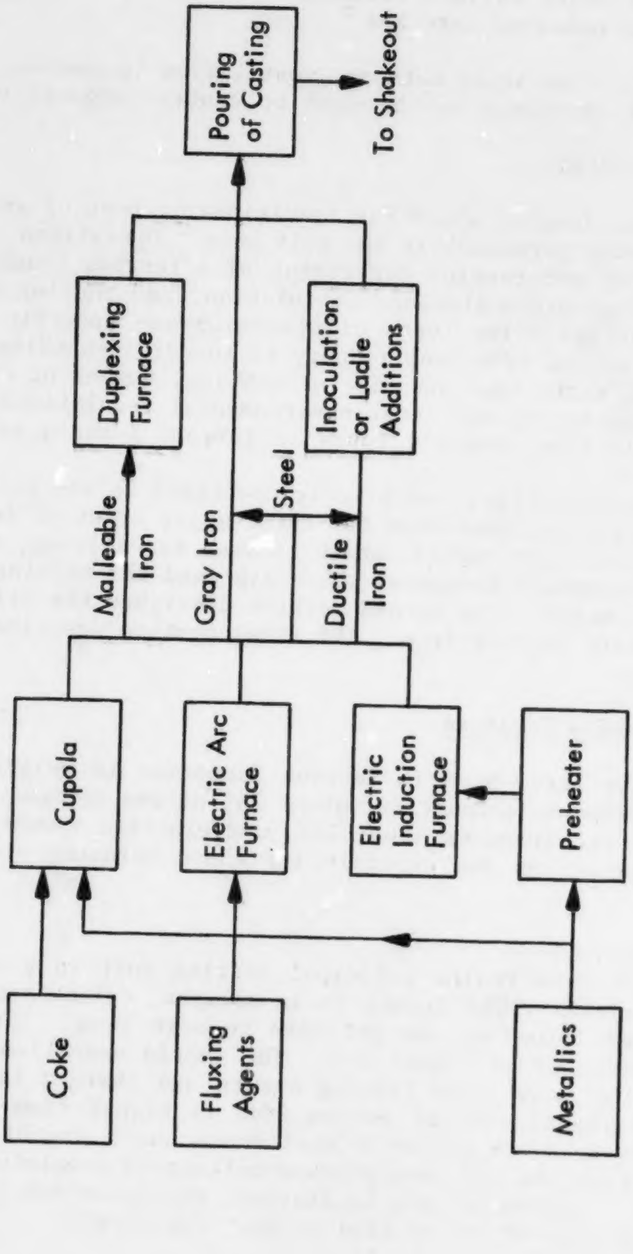
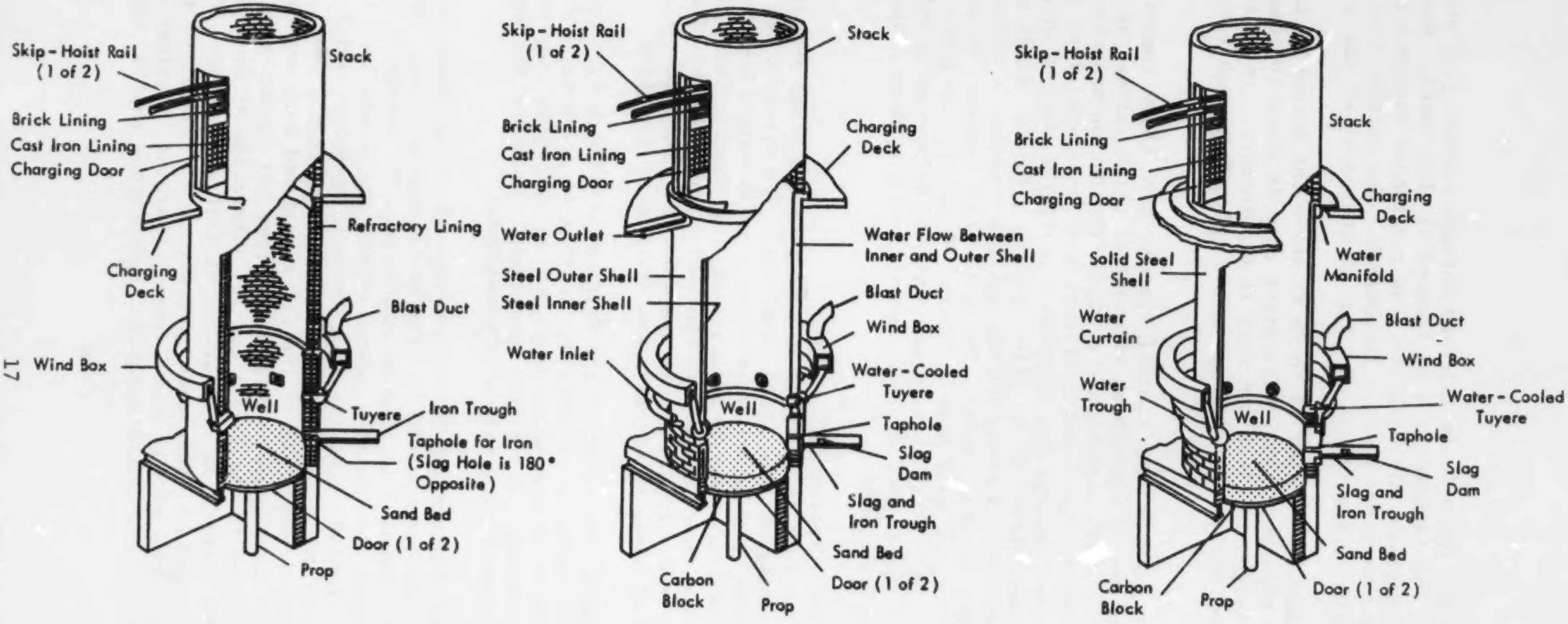

Coke
Fluxing Agents
Metallics
Cupola
Electric Arc Furnace
Electric Induction Furnace
Preheater
Malleable Iron
Gray Iron
Ductile Iron
Steel
Duplexing Furnace
Inoculation or Ladle Additions
Pouring of Casting
To Shakeout

Figure 2-6. Common flow diagram for ferrous foundry melt shops.


Skip - Hoist Rail (1 of 2)
Stack
Brick Lining
Cast Iron Lining
Charging Door
Refractory Lining
Charging Deck
Blast Duct
Wind Box
Well
Tuyere
Iron Trough
Taphole for Iron (Slag Hole is 180° Opposite)
Sand Bed
Door (1 of 2)
Prop
Skip - Hoist Rail (1 of 2)
Stack
Brick Lining
Cast Iron Lining
Charging Door
Charging Deck
Water Outlet
Water Flow Between Inner and Outer Shell
Steel Outer Shell
Steel Inner Shell
Blast Duct
Wind Box
Water Inlet
Water - Cooled Tuyere
Well
Taphole
Slag Dam
Slag and Iron Trough
Sand Bed
Carbon Block
Prop
Door (1 of 2)
Skip - Hoist Rail (1 of 2)
Stack
Brick Lining
Cast Iron Lining
Charging Door
Charging Deck
Solid Steel Shell
Water Manifold
Water Curtain
Blast Duct
Wind Box
Water Trough
Well
Water - Cooled Tuyere
Taphole
Slag Dam
Slag and Iron Trough
Sand Bed
Carbon Block
Prop
Door (1 of 2)

Conventional Cupola

Water - Cooled Cupola (Water - Wall)

Water - Cooled Cupola (Flood Cooled)

Figure 2-7. Three types of cupola furnaces.[9]

Combustion air for the melt is injected through tuyeres just above the level of the sand. The taphole is also located at this level. For continuously operating cupolas, the slag and iron are tapped together and the slag skimmed off in the runner or in a forehearth. For intermittent operations, the slag hole is located at the top of the level of the iron.

The charging door is located 15 to 25 ft above the bottom of the cupola, usually on a separate floor. The stack extends above the charging door to sufficient height to clear the roof of the foundry. In most cupolas this stack is capped and the exhaust gases are emitted through a control device.

In most modern cupolas, the control systems have three components. First, the gases are passed through an afterburner which raises the temperature to about 1300°C. This afterburner oxidizes the carbon monoxide to carbon dioxide and burns any tars and oils that were liberated from dirty scrap. The gas stream then passes through a cooling mechanism which may rely on radiant, evaporative, or dilution cooling. For hot blast cupolas (cupolas which inject heated blast air through the tuyeres) a radiant air-to-air heat exchanger is most common. For cold blast cupolas, an evaporative spray chamber is the most common device. Finally, the gases pass through a fabric filter or high energy wet scrubber before being exhausted to the atmosphere. Figure 2-8 shows a schematic of a typical evaporative cooler and wet scrubber system.

2.3.1.2 Electric Arc Furnace--

The electric arc furnace is found in both iron and steel foundries and is the principal melting unit in steel foundries. The electric arc furnace is a refractory-lined, cup-shaped vessel with a refractory-lined roof. As with the cupola, the lining may be either acidic or basic. Three graphite electrodes are placed through holes in the roof to provide the electrical energy for melting iron. Figure 2-9 is a schematic of an electric arc furnace, and Figure 2-10 shows an electric arc furnace in operation.

Unlike the cupola, the electric arc furnace is a batch type operation; its production cycle consists of charging, melting or refining, and tapping. Two additional steps that are often found are backcharging and, in steel foundries, oxygen lancing. These five operational steps and the associated emissions are described in the following paragraphs.

An electric arc furnace can be charged through a side door, or the roof can be removed so the furnace can be charged through the top. The top charging method predominates in ferrous foundries. The charge is introduced to the furnace through the use of a charge bucket or, in smaller, less mechanized foundries, by hand. Top charging produces emissions which are not controlled in most of the existing plants. Emissions result from: (a) vaporization and partial combustion of the oil introduced with any scrap, borings, turnings, and chips contained in the charge; (b) oxidation of organic matter which may adhere to the scrap; and (c) liberation of sand particles introduced into the furnace on the surface of casting returns. High oil content is characteristic of the least expensive scrap (swarf, or turnings, chips, and borings, from machine operations). Charging emissions are made up of particulate matter, carbon monoxide, hydrocarbon vapors, and soot.

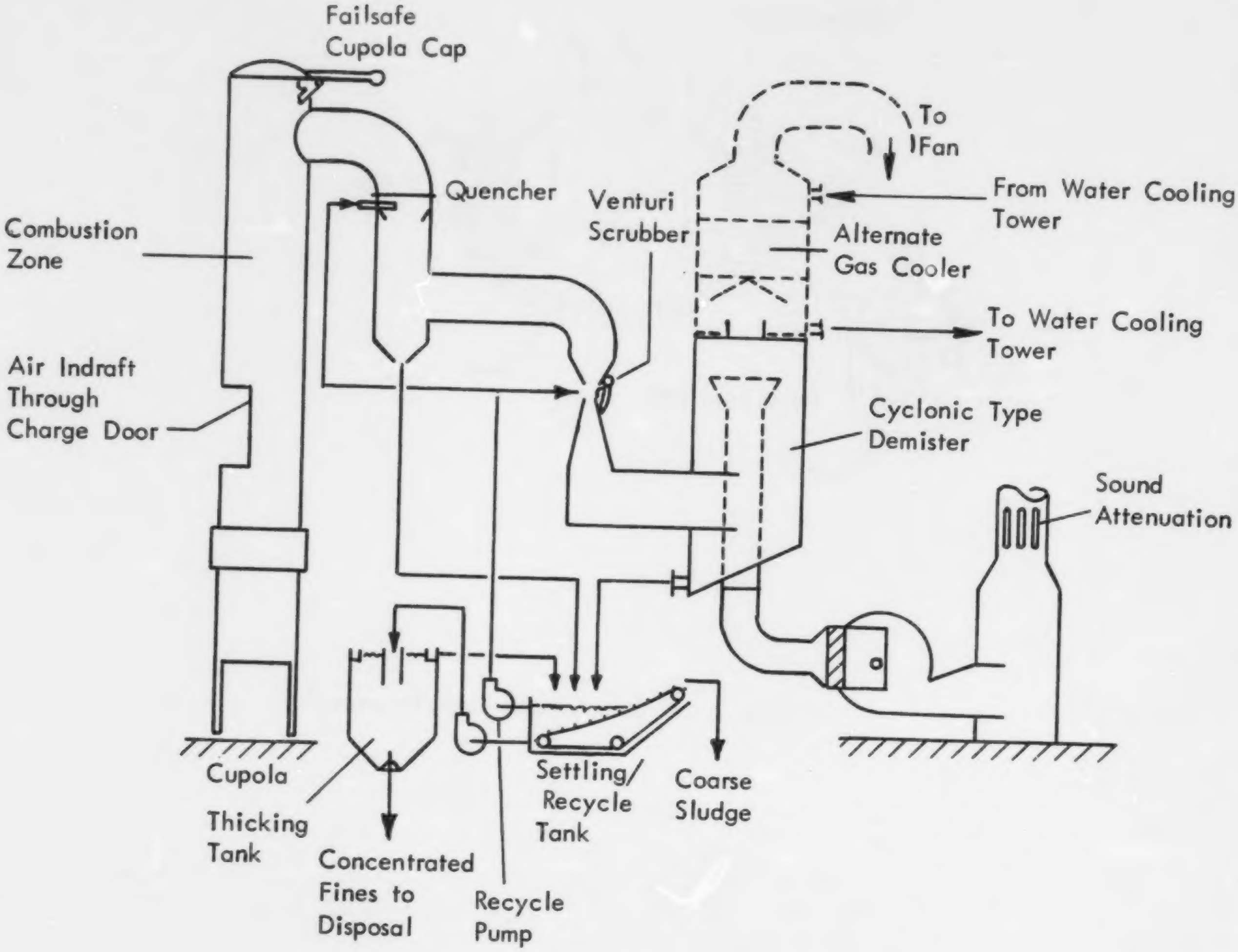

Failsafe Cupola Cap
To Fan
Quencher
Venturi Scrubber
From Water Cooling Tower
Combustion Zone
Alternate Gas Cooler
To Water Cooling Tower
Air Indraft Through Charge Door
Cyclonic Type Demister
Sound Attenuation
Cupola
Settling/ Recycle Tank
Coarse Sludge
Thicking Tank
Concentrated Fines to Disposal
Recycle Pump

Figure 2-8. Typical cupola scrubber system.[10]

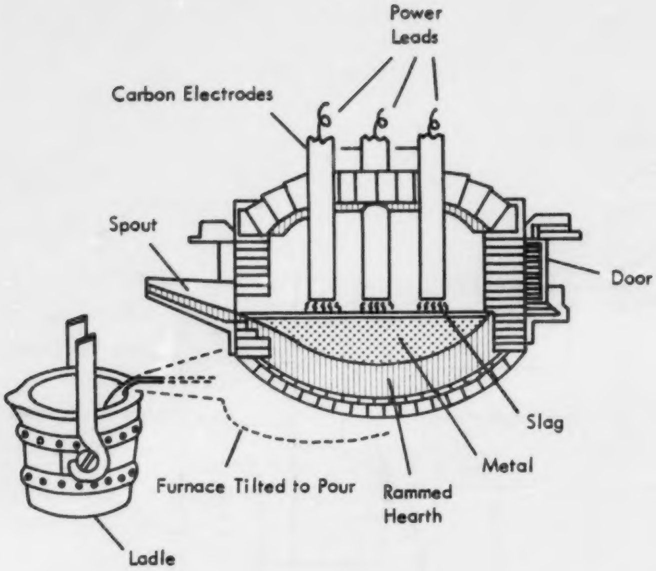

Power
Leads
Carbon Electrodes
Spout
Door
Slag
Metal
Furnace Tilted to Pour
Rammed
Hearth
Ladle

Figure 2-9. An electric arc furnace.[2]

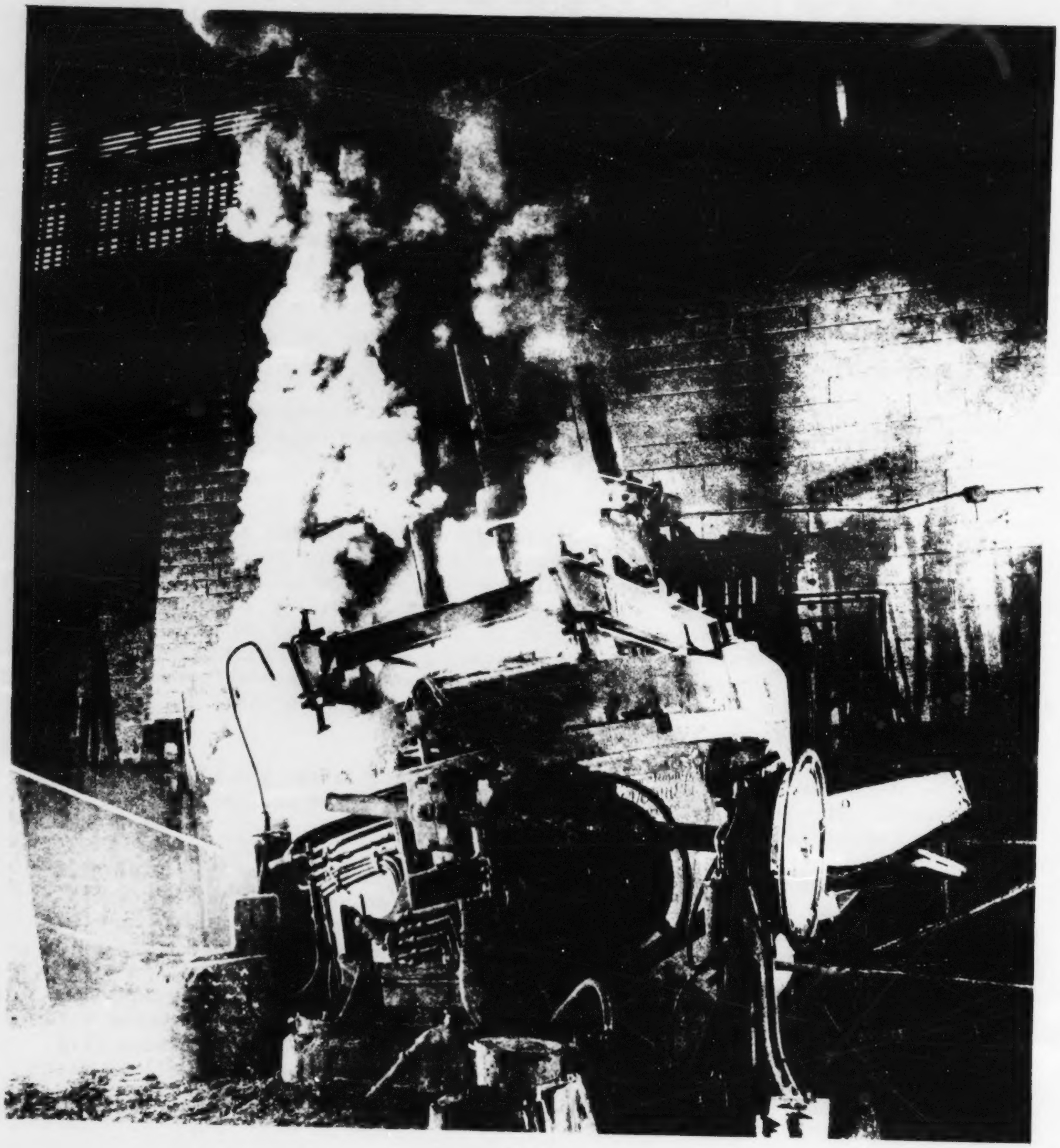


Figure 2-10. An electric arc furnace controlled by a canopy hood during tapping.[11]

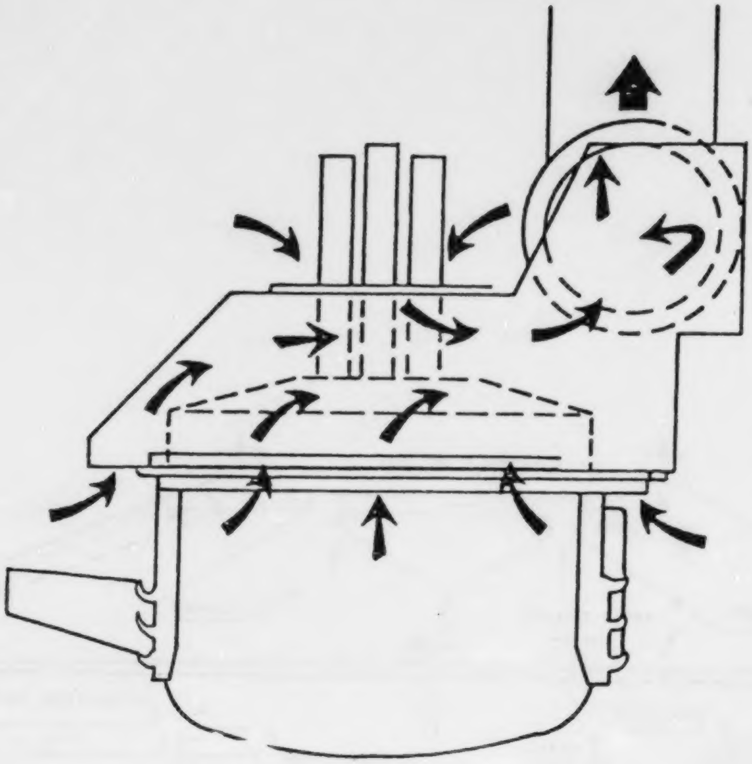
When the furnace is ready for the melting cycle, the electrodes are lowered through the roof to a position about 1 in. above the metallic charge and then energized. Melting is accomplished from the heat supplied by radiation from the arc formed between the electrodes and the metallic charge, radiation from the furnace lining, and resistance of the metal between the arc paths. During melting operations (meltdown, slagging, and refining), emissions consist of: (a) particulates as metallic and mineral oxides generated from vaporization of iron and transformation of mineral additives; (b) carbon monoxide from combustion losses of the graphite electrodes, carbon raisers, and carbon in the metal; and (c) hydrocarbons from vaporization and partial combustion of oil remaining in the charge. During melting, emissions escape from the furnace through electrode annuli (holes), the slag doors, the roof ring (the joint between the furnace shell and roof), and sometimes the tap spout.[12]

Steel furnaces are sometimes backcharged; that is, a second charge is added to the furnace as soon as sufficient volume is available in the furnace. (Iron furnaces are generally charged only one time.) Backcharging produces a violent eruption of emissions with a strong thermal driving force. The amount of pollutants generated during this phase of the operation is probably greater than during either the first charge or during treatment of the molten bath in the transfer ladle.[13]

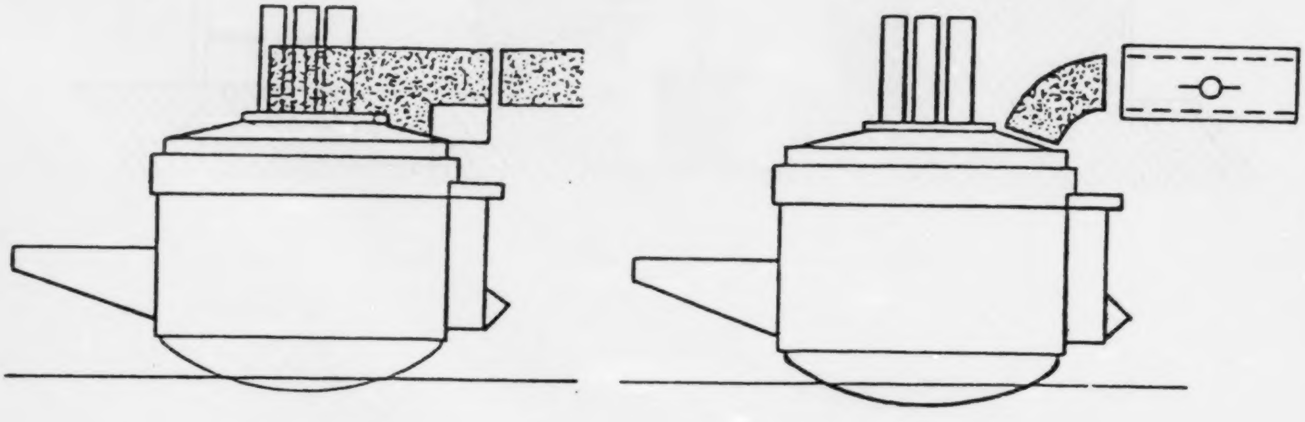
Oxygen lancing in steel furnaces is used mainly for adjusting of the chemistry of the steel, for speeding up of the melting process, and for superheating the bath. Oxygen lancing results in increased temperature, gas evolution, and generation of particulates (particularly iron oxide) and carbon monoxide. Oxygen lancing can be carried out with moderate rates of oxygen addition, thereby avoiding generating excessively high temperatures, gas evolution, and particulate emissions. However, extended periods of oxygen lancing can increase energy consumption, refractory wear, and oxidation of the bath and can change the production rate.

When the melting and refining cycle is completed, the electrodes are raised. The furnace is then tilted by as much as 45 degrees, and the refined metal is tapped into a ladle.

Most electric arc furnace emissions are controlled by fabric filters. However, the mechanisms used to capture these emissions vary considerably. Figures 2-11 through 2-14 depict five common methods of emission capture: side draft hoods, roof hoods, direct shell evacuation, canopy hoods, and multiple close capture hooding. The roof hood, side draft hood, and direct shell evacuation systems shown in Figure 2-11 are effective in capturing emissions only during melting and refining. The canopy hood system (if cross drafts are eliminated) (Figure 2-12) and close capture system (Figures 2-13 and 2-14) capture charging and tapping emissions as well as melting emissions.



Roof Hood



Side Draft Hood

Direct Shell Evacuation

Figure 2-11. Roof hood, side draft hood, and direct shell evacuation for capturing electric arc furnace emissions.[14]

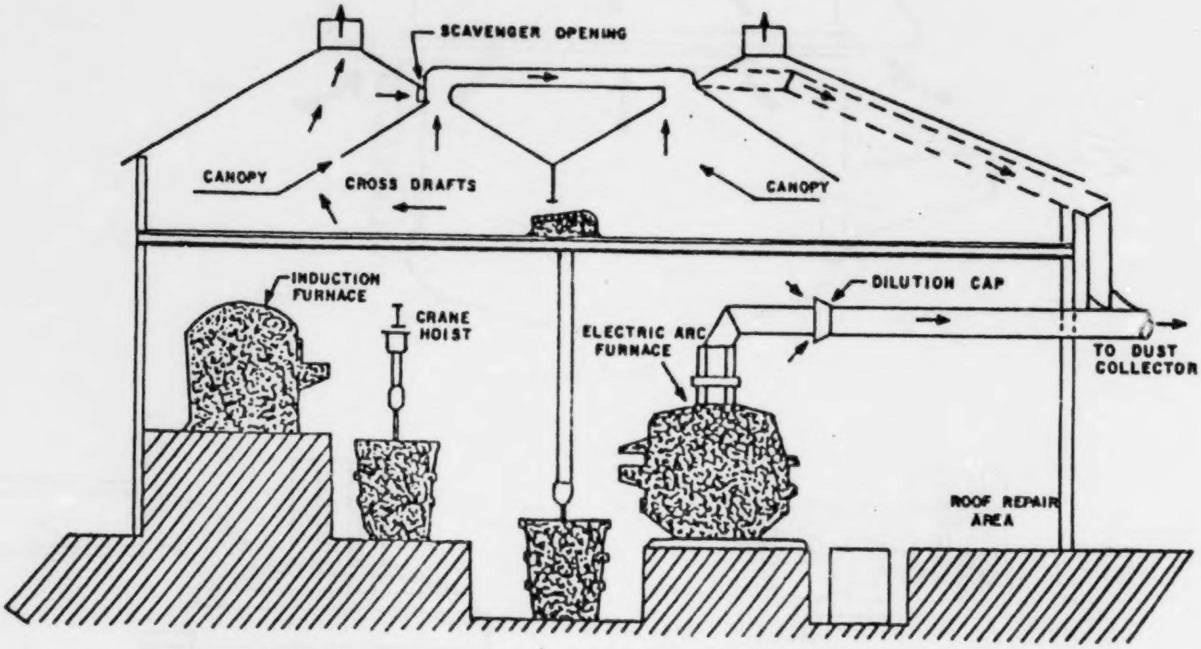

SCAVENGER OPENING
CANOPY
CROSS DRAFTS
CANOPY
INDUCTION FURNACE
CRANE HOIST
ELECTRIC ARC FURNACE
DILUTION CAP
TO DUST COLLECTOR
ROOF REPAIR AREA

Figure 2-12. Canopy hood for capturing electric arc furnace emissions.14

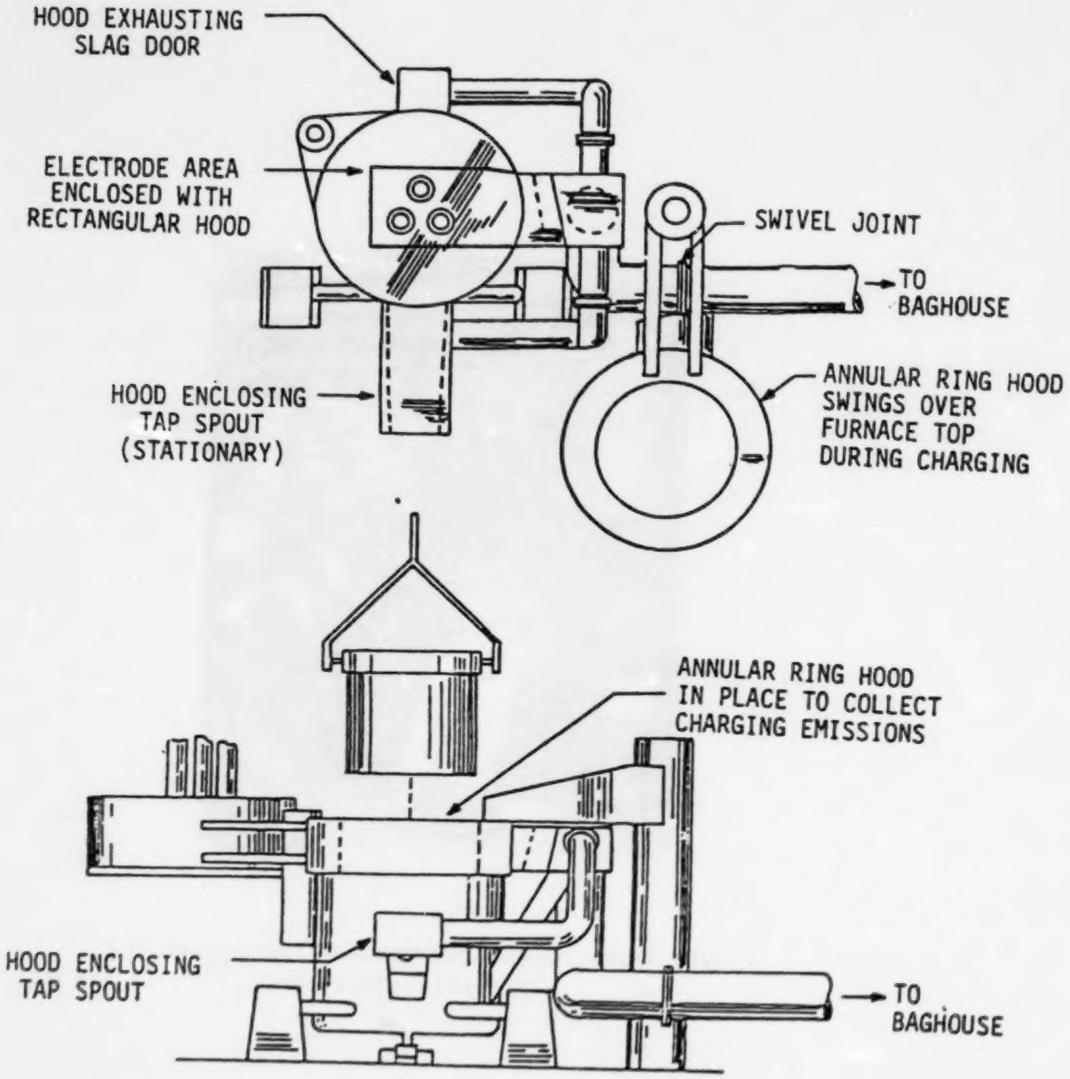

HOOD EXHAUSTING SLAG DOOR
ELECTRODE AREA ENCLOSED WITH RECTANGULAR HOOD
SWIVEL JOINT
TO BAGHOUSE
HOOD ENCLOSING TAP SPOUT (STATIONARY)
ANNULAR RING HOOD SWINGS OVER FURNACE TOP DURING CHARGING
ANNULAR RING HOOD IN PLACE TO COLLECT CHARGING EMISSIONS
HOOD ENCLOSING TAP SPOUT
TO BAGHOUSE

Figure 2-13. Hawley close capture hoods for capturing electric arc furnace emissions.[14]

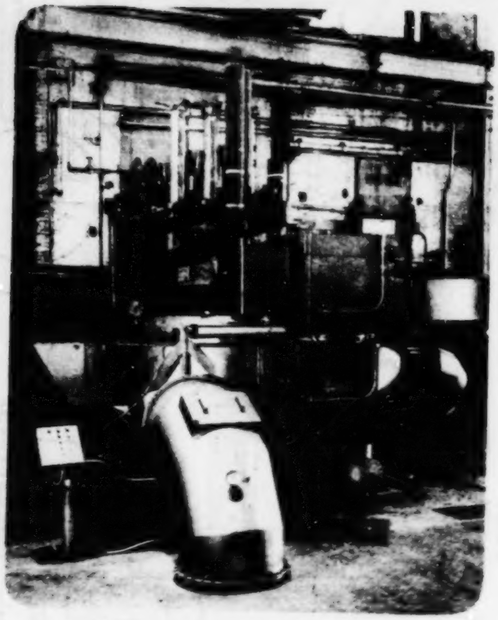


Figure 2-14. Close capture hooding system for electric arc furnace.[15]

2.3.1.3 Electric Induction Furnace--

Although some foundries use the channel induction furnace, the coreless induction furnace is more frequently used for iron melting, as shown in Figure 2-15. The coreless induction furnace is a cup-shaped vessel which uses electrical energy to induce eddy currents in the metallic charge to produce molten iron. Since wet or oily scrap can lead to explosions in a furnace, the scrap is generally cleaned and often preheated before charging. Clean scrap generally results in little particulate emission and no carbon monoxide and hydrocarbon emission. As a result of the low pollutant levels, induction furnaces are finding increased use in ferrous foundries. Those furnaces which are controlled generally have a close capture hooding system vented to a fabric filter, such as the one shown in Figure 2-16 .

2.3.2 Inoculation

Iron inoculation is an operation used primarily in the production of ductile iron. During inoculation a nodulizing agent, most frequently magnesium, is added to the molten gray iron. This agent causes the flaked carbon found in gray iron to become graphite spheroids. This chemical transformation produces a material which is less brittle than gray iron.

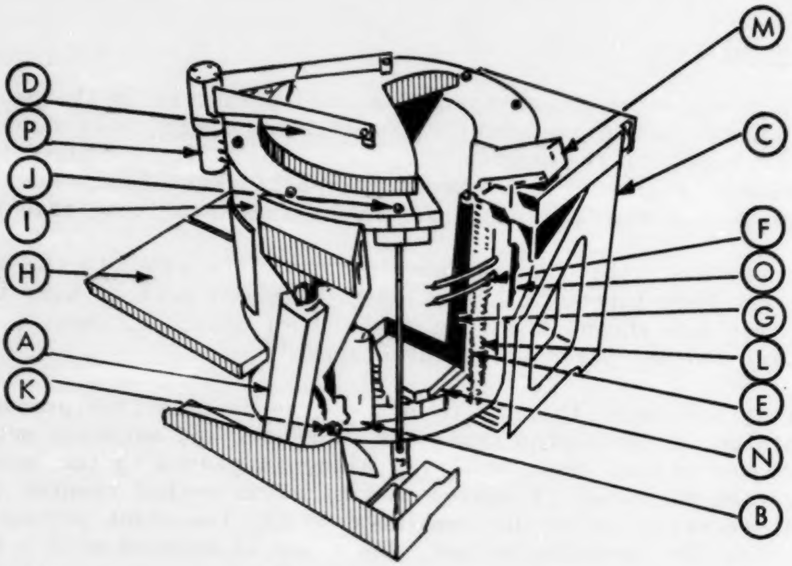
The magnesium (or other nodulizing agent) is added to the molten metal after it has been tapped into the ladle. Several methods used to inoculate ductile iron are shown in Figure 2-17. Modl describes these processes in more detail and discusses their advantages.[16]

Matter indicates that 75 to 80% of the ductile iron produced in the United States is inoculated using the pour-over and sandwich methods.[17] In the pour-over method the nodulizing alloy is placed in the bottom of the ladle and the hot metal is poured on top. This method results in 20 to 30% inoculant recovery, with the remainder of the inoculant emitted as a fine oxide. With the sandwich method, the alloy is covered with 1 to 2% steel punching or plate or ferrosilicon. This allows more hot metal to be poured before the reaction starts and results in magnesium recovery of 40 to 50%.[17]

Industry personnel indicate that newer methods of inoculation are resulting in a magnesium recovery of 50 to 90%.[15] One method which shows particular promise inoculates the metal in the mold rather than in the ladle. Matter indicates that magnesium recoveries of 80 to 90% have been obtained with in-mold inoculation.[17]

2.3.3 Pouring and Cooling

The final operation in metal casting is the pouring of the molten iron into the mold and the subsequent cooling of the casting. The types of pouring operations found in ferrous foundries vary widely depending upon the type of mold used and the degree of mechanization in a given foundry. Pouring and cooling operations involving sand molds, the mold making most frequently found in foundries, is discussed in the following paragraphs. Pouring of metal into sand molds also has a greater potential for emissions than pouring into permanent molds. Two major classes of pouring operations, mechanized pouring lines and floor pouring, are described.



A. Hydraulic tilt cylinders
B. Shunts
C. Stanchion
D. Cover
E. Coil
F. Leads
G. Working refractory
H. Operator's platform

I. Steel shell
J. Tie rods
K. Clamping bolts
L. Coil support
M. Spout
N. Refractory brick
O. Access port
P. Lid hoist mechanism

Figure 2-15. A coreless electric induction furnace.[18]

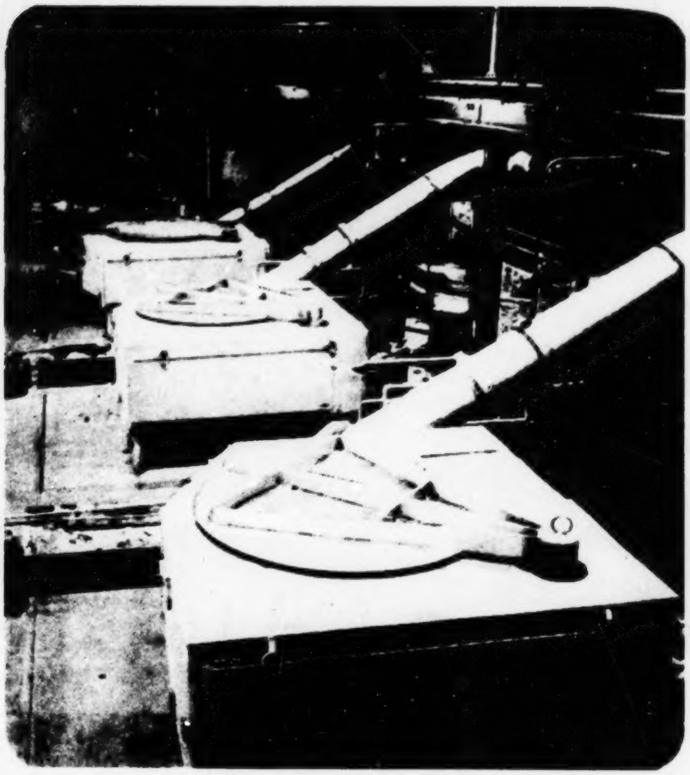


Figure 2-16. Close capture hooding system for electric induction furnace.[15]

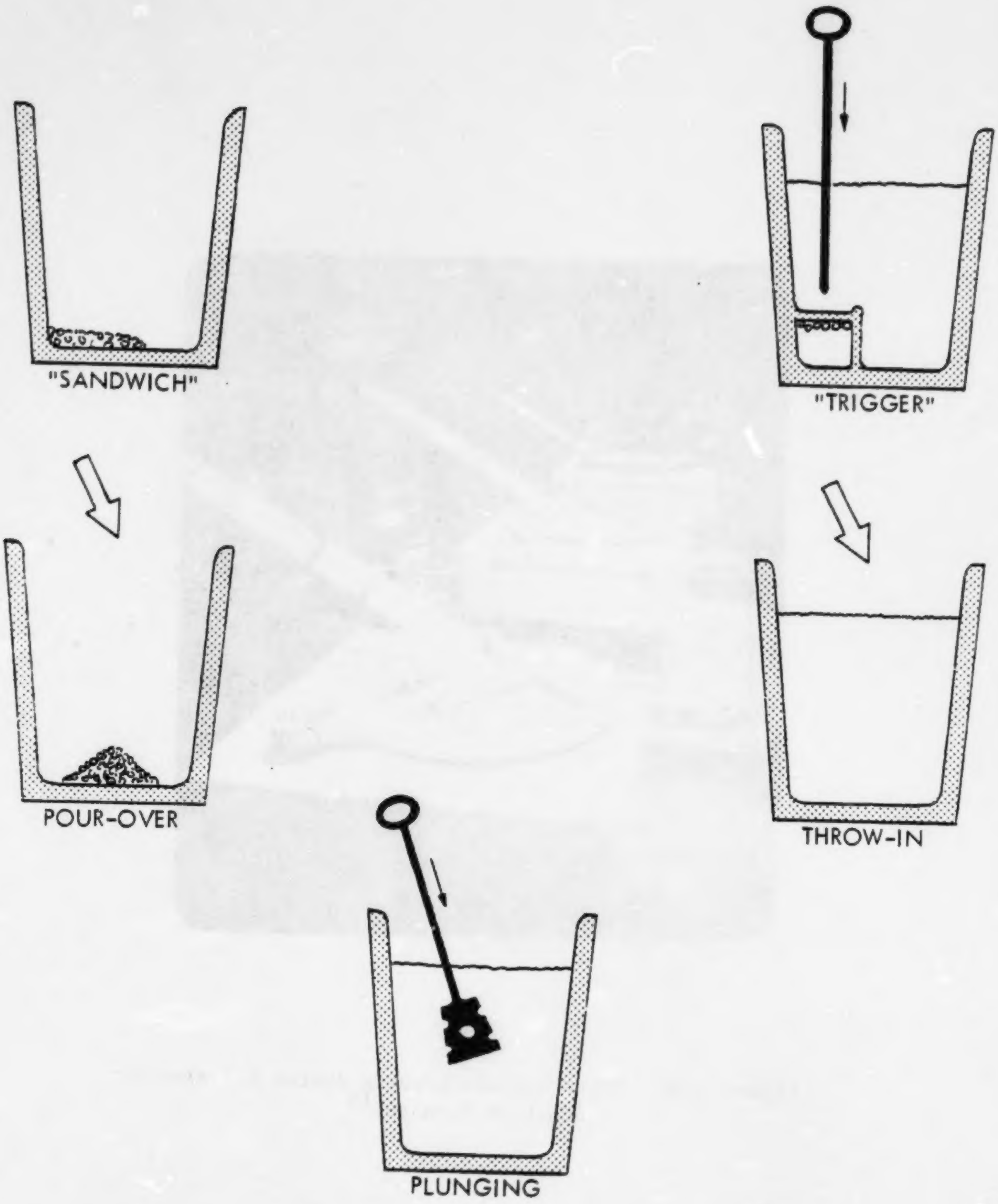

"SANDWICH"
"TRIGGER"
POUR-OVER
THROW-IN
PLUNGING

Figure 2-17. Methods of iron inoculation methods used to inoculate ductile iron.[16]

Mechanized pouring lines are generally found in medium to large foundries which produce small- to medium-sized castings. The pouring line has one or more pouring ladles located along a conveyor. These ladles may be stationary or may be capable of moving parallel to the conveyor. The molds are placed on a conveyor and moved to the pouring station. After the pouring operation is completed, the mold and casting are carried by the conveyor through a cooling area, often an enclosed "tunnel" made of sheet metal.

Floor pouring is found in small- to medium-sized foundries which generally do not have sufficient capital to finance mechanization, and in larger foundries which produce castings that are too large to be transported by conveyor. In these foundries the mold is placed on an open floor or in a pit, and the ladle is transported to the mold generally by an overhead trolley. When the ladle reaches the mold, the molten iron is poured into the mold and the casting is then cooled in place.

No controlled pouring and cooling operations were identified by EPA studies. For floor pouring and pit molds no capture methods were identified. For mechanized pouring lines, ventilation systems, such as that shown in Figure 2-18 are often installed although no installations were identified in which the exhausts from such systems were vented to an air pollution control device.

2.4 CLEANING AND FINISHING

After the casting has cooled, it is removed from the mold, cleaned, and finished into a final product. A flow diagram of the cleaning and finishing process is presented in Figure 2-19.

A number of techniques are available to perform each of the operations shown in Figure 2-19. The choice of technique depends on the type of metal cast, the type of mold, the size of the casting, and the degree of mechanization in the foundry.

Because of the wide variety of cleaning practices, it is not possible to describe what process an inspector might find in a particular foundry. The following paragraphs trace the flow of the casting through the cleaning room. Whenever possible, pictures or diagrams of the major pieces of equipment used to perform the various operations are included. Also described are some of the ventilation systems used to capture emissions. Captured emissions are generally exhausted through a fabric filter and either vented to the atmosphere or recycled to the foundry.

After the casting has cooled, it must be removed from the mold. If a sand mold is used, this process is generally called shakeout. Shakeout methods probably vary more from plant to plant than any other operation with the possible exception of mold and coremaking. In foundries where large pit molds are used, the sand is often removed from the mold with front end loaders and shovels. In small, unmechanized foundries methods consist of dumping the molds onto the floor, using pneumatic tools to break the sand loose, and manually removing the sand with shovels.

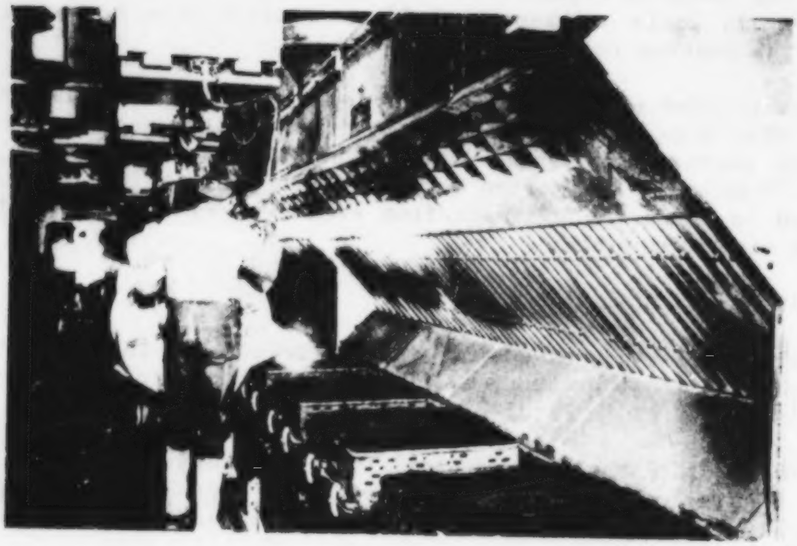


Figure 2-18. A 33,000-cfm compensating hood on the pouring line.[19]

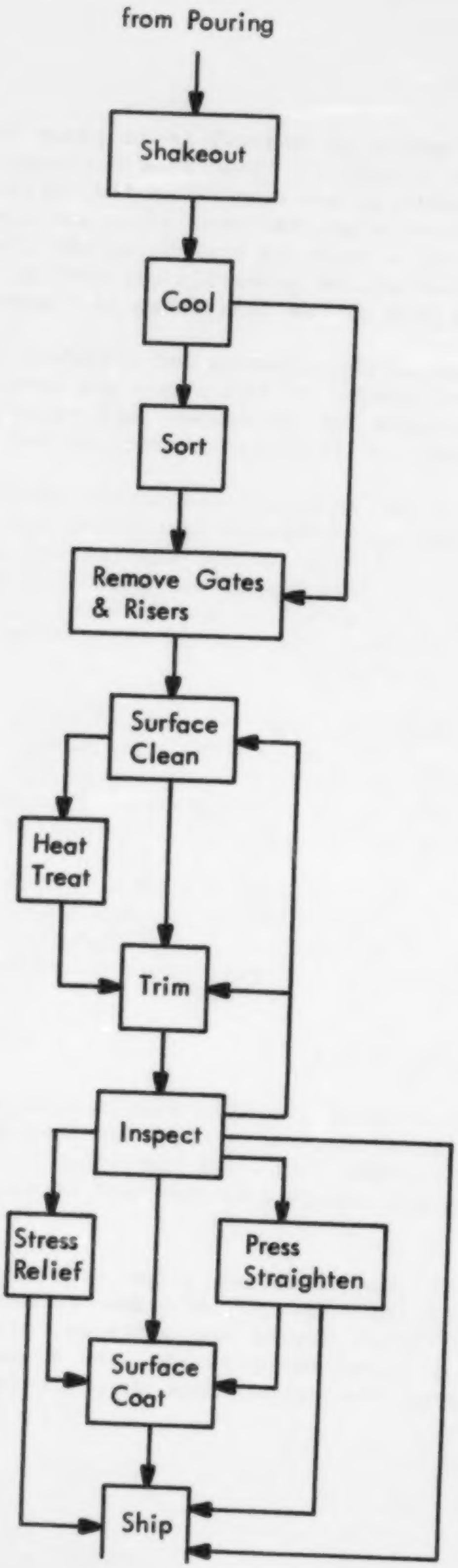

from Pouring
Shakeout
Cool
Sort
Remove Gates & Risers
Surface Clean
Heat Treat
Trim
Inspect
Stress Relief
Press Straighten
Surface Coat
Ship

Figure 2-19. Flow diagram of cleaning and finishing process.[18]

The most typical method of removal is to place the flask on a vibrating screen. The sand is knocked loose from the casting and falls through the screen, and the castings are carried on the vibrating screen to a conveyor and then moved on to other the next cleaning step. One newer method of shakeout substitutes a rotating screen for the traditional vibrating screen. Emissions from shakeout are generally captured by either a hood enclosure or a side draft hood such as the ones shown in Figures 2-20 and 2-21.

The next step in the cleaning and finishing process is removal of the sprues, gates, and risers, if these have not been knocked off during shakeout. These appendages can be knocked off manually with hammers; cut off with abrasive, band, or friction cutting; or removed with an oxygen torch.

Examples of abrasive cutoff and oxygen cutting are shown in Figures 2-22 and 2-23. The ventilation system associated with appendage removal will depend upon the size and shape of the casting and the method of removal. With larger castings where oxygen cutting is used, a booth with air exhaust such as the one shown in Figure 2-23 may be used. In other cases downdraft benches or close capture type hooding systems may be used. Often these operations are not controlled.

After the appendages are removed, chipping hammers and various types of grinders are used to remove other irregularities from the casting. Again, the method of emission control is dependent upon the size and shape of the casting and the type of tool being used. Figures 2-24, 2-25, and 2-26 show examples of controlled chipping and grinding emissions.

Finally, the castings are subjected to blast cleaning or tumbling to remove the remaining scale or burned on sand. Both shot and sand blasting are used in ferrous foundries. A typical abrasive blast system is shown in Figure 2-27. Generally, the blast unit is enclosed and air is exhausted to a fabric filter.

2.5 SAND HANDLING SYSTEM

In foundries which practice sand molding, the sand is reused many times. In a typical system the sand is removed from the shakeout hopper, reconditioned to remove lumps and any metallics that have fallen through the shakeout grate, and returned to the sand storage bins before being used in the muller.

The specific sand handling steps vary depending upon the degree of mechanization in the foundry. At unmechanized foundries the sand may be dumped onto the floor during the shakeout, transferred manually by front end loader to a screening operation, and transferred manually again to a storage pile near the muller from where it is manually charged to the muller.

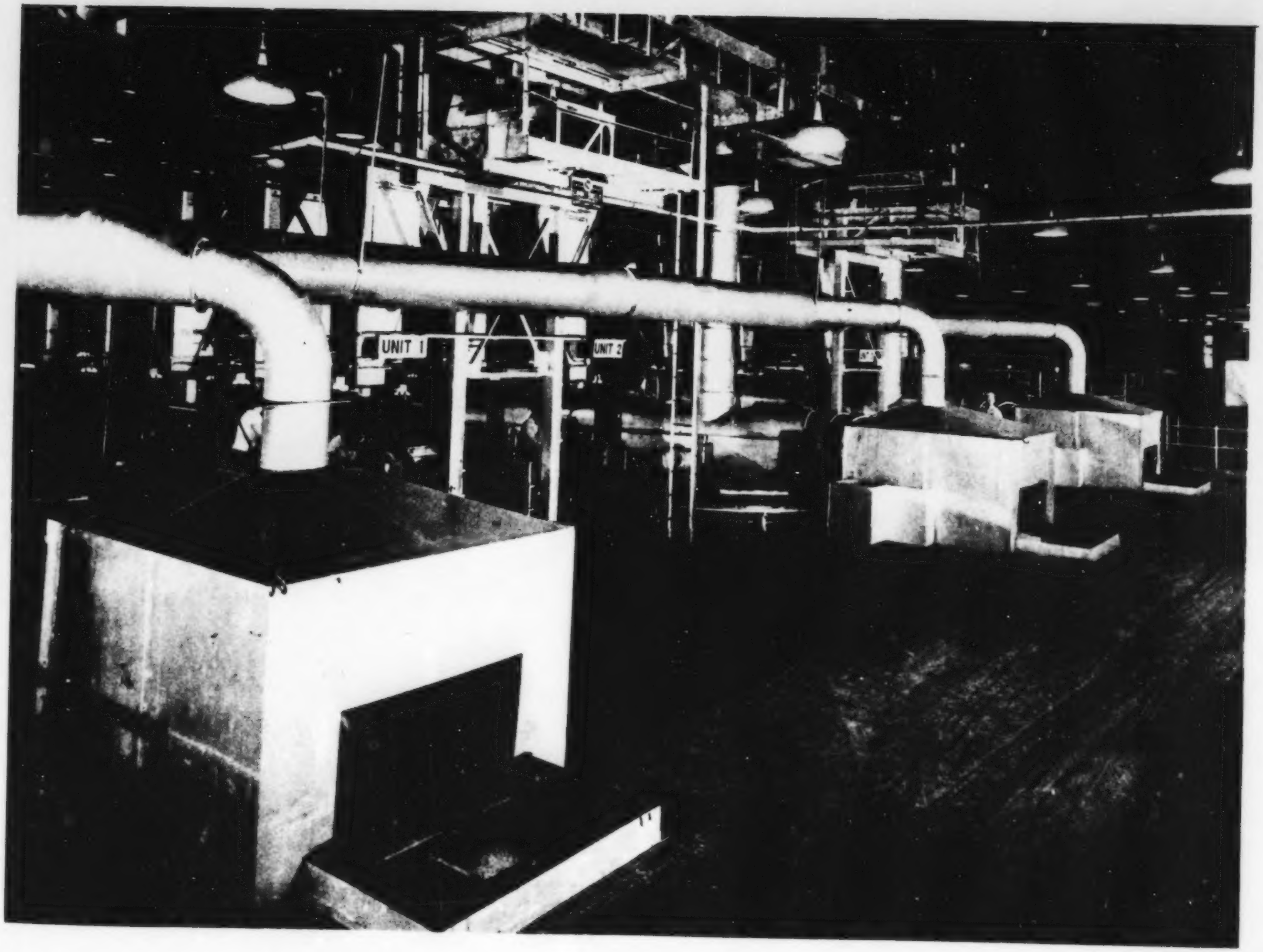


Figure 2-20. Three enclosed shakeouts, automatic discharge mold conveyor lines and sand distribution. Casting conveyor brings castings from tunnel to working level on floor where castings are desprued and sorted. Part of a complete handling and preparation system.[3]

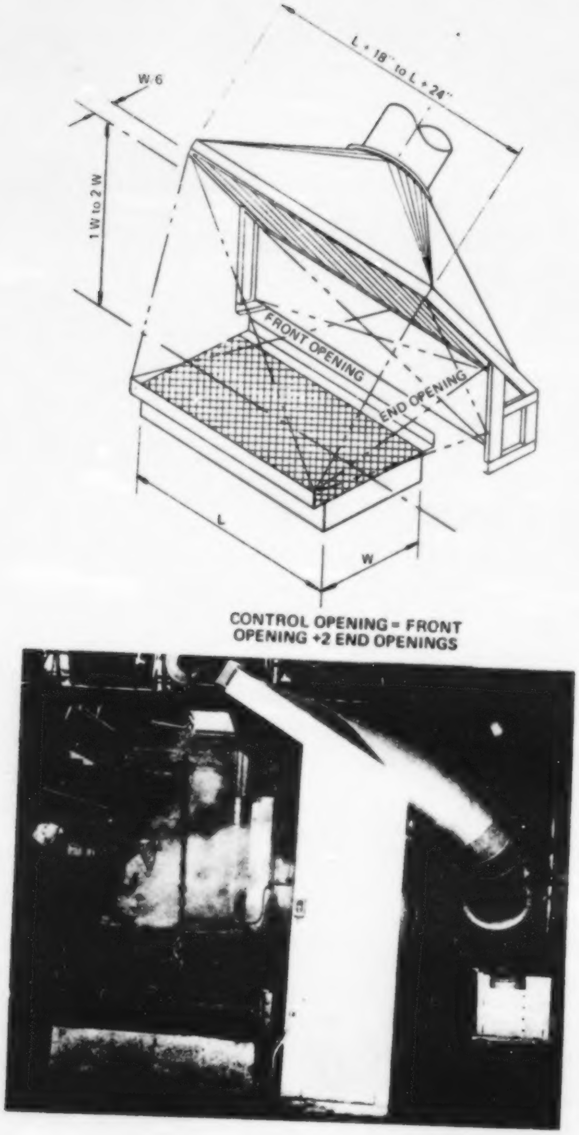

L + 18" to L + 24"
W/6
1 W to 2 W
FRONT OPENING
END OPENING
L
W
CONTROL OPENING = FRONT OPENING +2 END OPENINGS

Figure 2-21. Side draft shakeout hood.[3]

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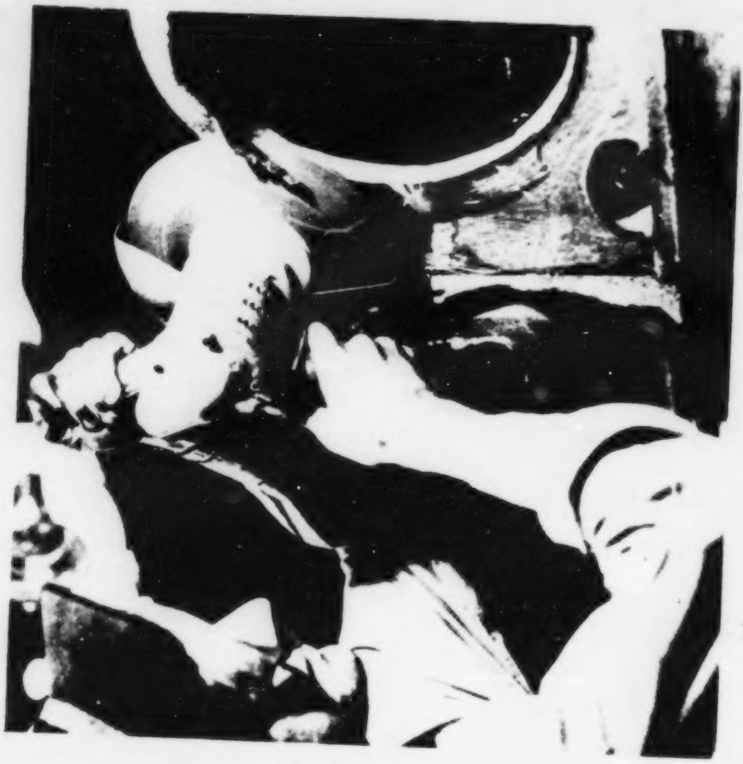
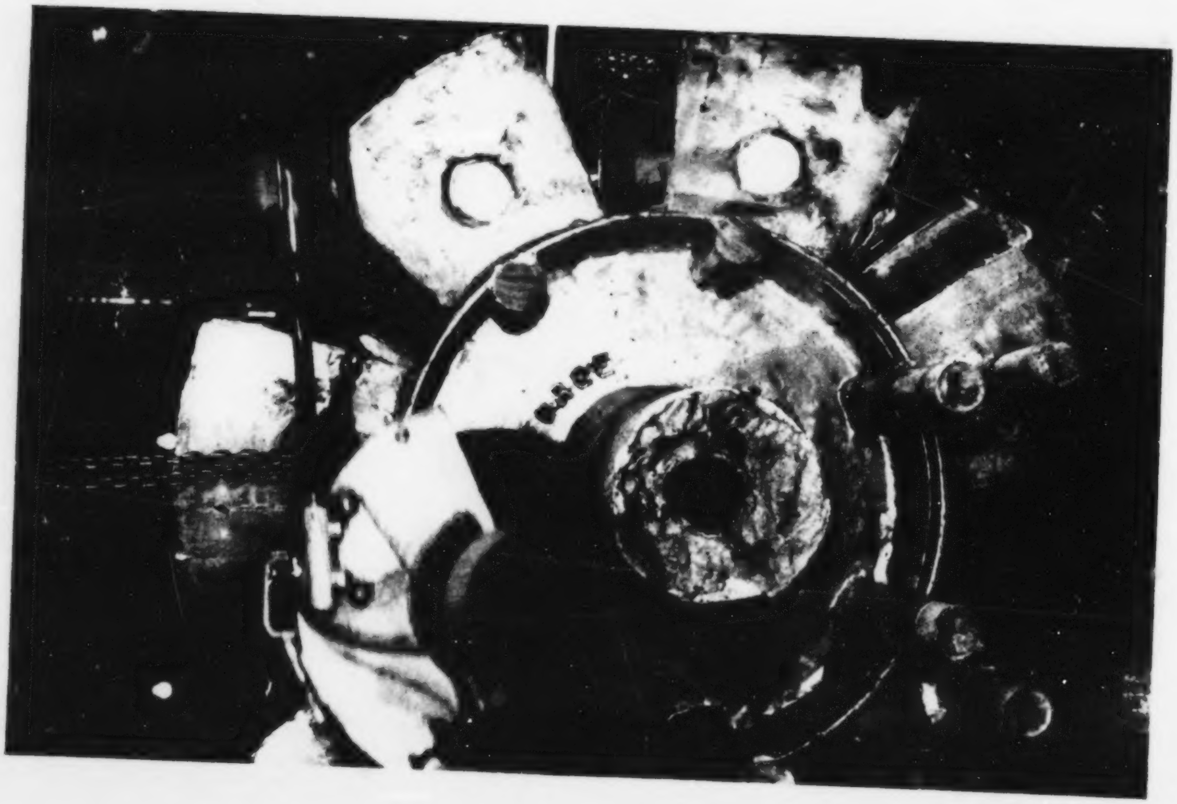
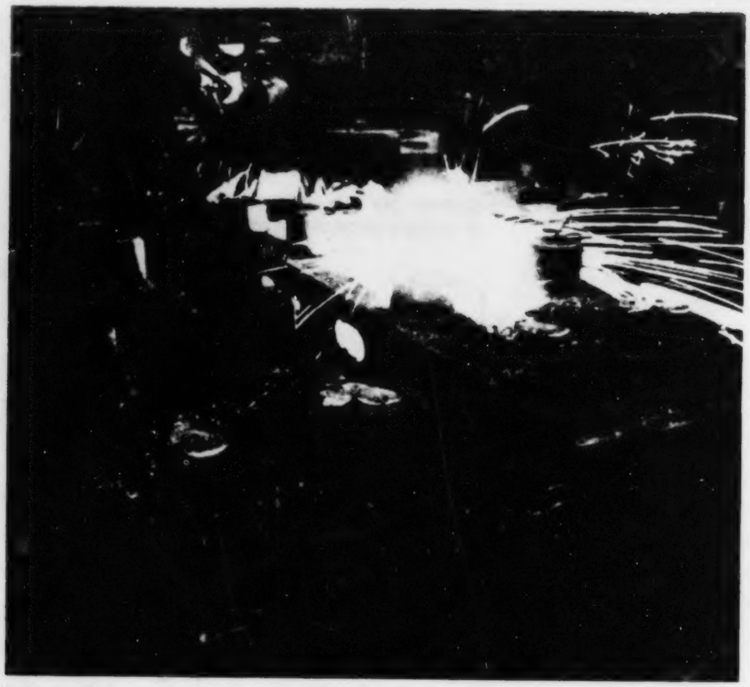
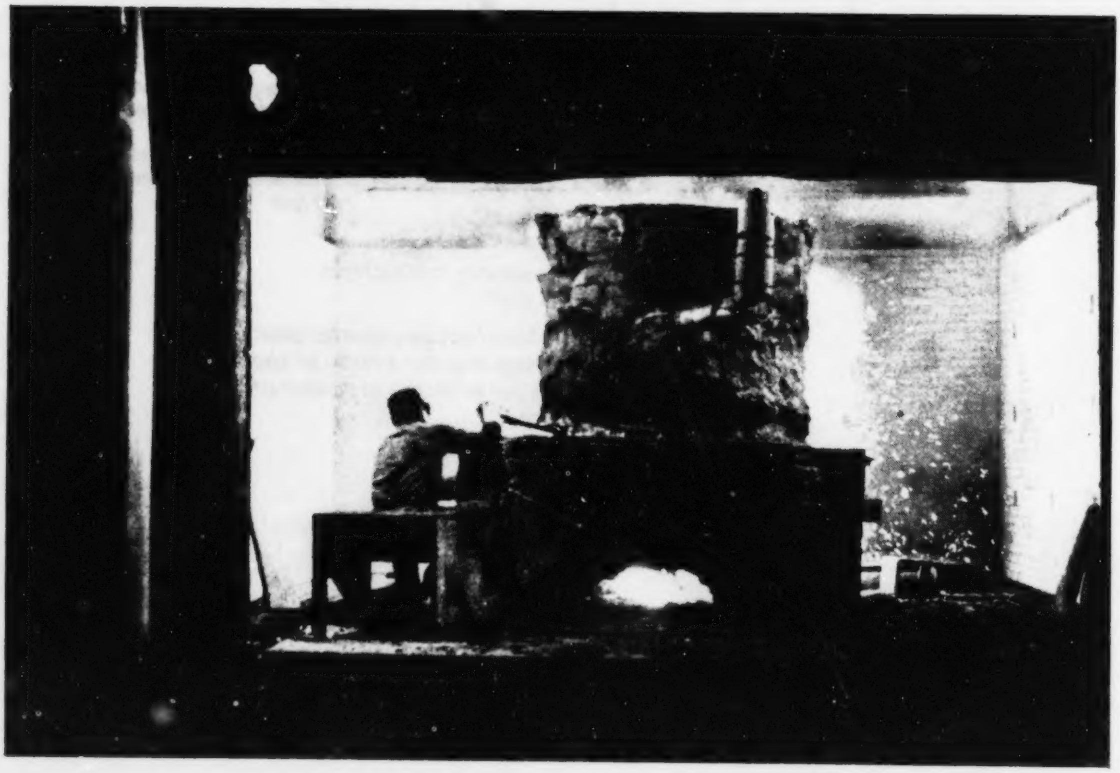


Figure 2-22. Abrasive cutoff of sprues and risers in cleaning and finishing process.[20]





(a)



(b)

Figure 2-23. Torch cut-off of risers in cleaning and finishing process.[8,20]

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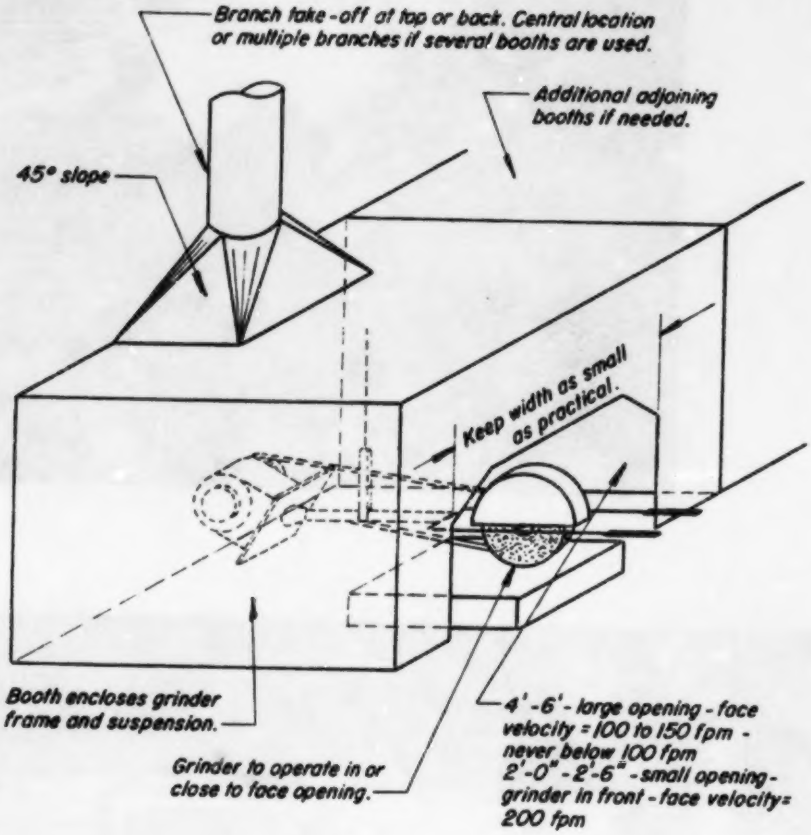
Branch take-off at top or back. Central location or multiple branches if several booths are used.
Additional adjoining booths if needed.
45° slope
Keep width as small as practical.
Booth encloses grinder frame and suspension.
Grinder to operate in or close to face opening.
4'-6' - large opening - face velocity = 100 to 150 fpm - never below 100 fpm
2'-0" - 2'-6" - small opening - grinder in front - face velocity = 200 fpm

Minimum duct velocity = 3000 fpm
Entry loss = 0.5 VP

NOTE: Small local exhaust hoods mounted behind grinder wheel may trap the stream of sparks, but are usually not effective in control of air-borne dust.

Figure 2-24. Swing grinder booth.[21]

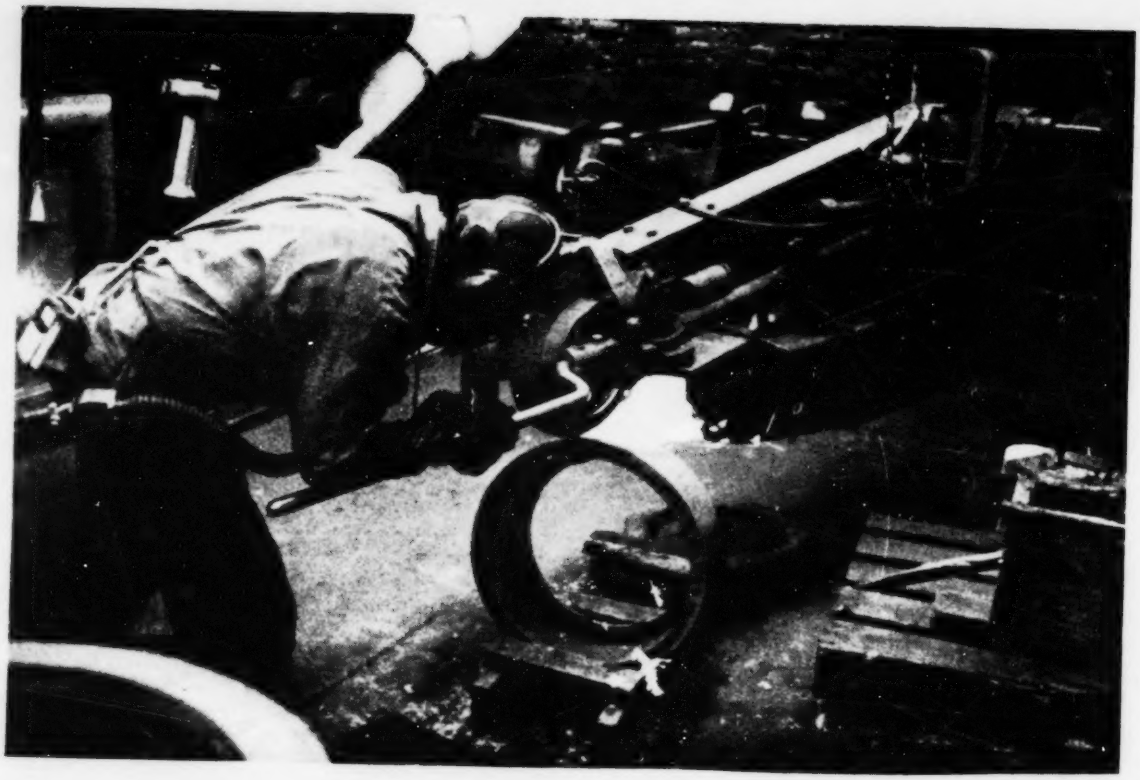

Figure 2-25. Swing grinding operation. The hood chute is adjusted to capture the entire grinding swarf.[8]

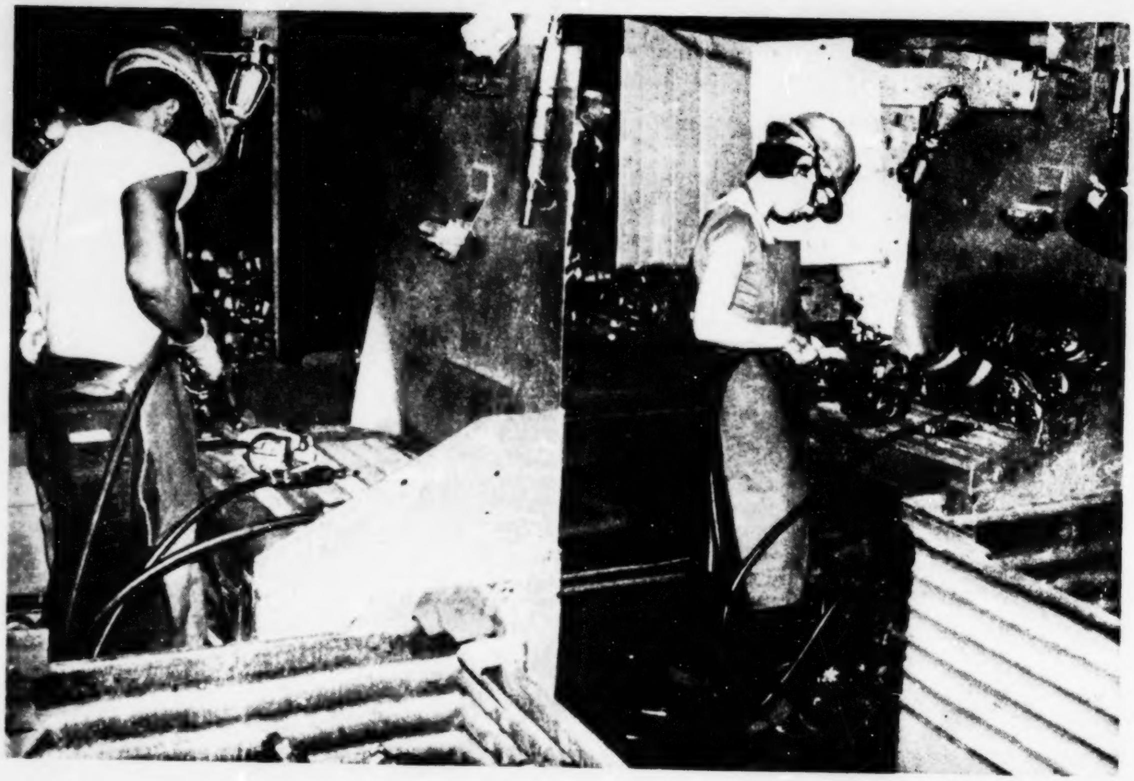

Figure 2-26. Downdraft chipping and grinding bench.[8]

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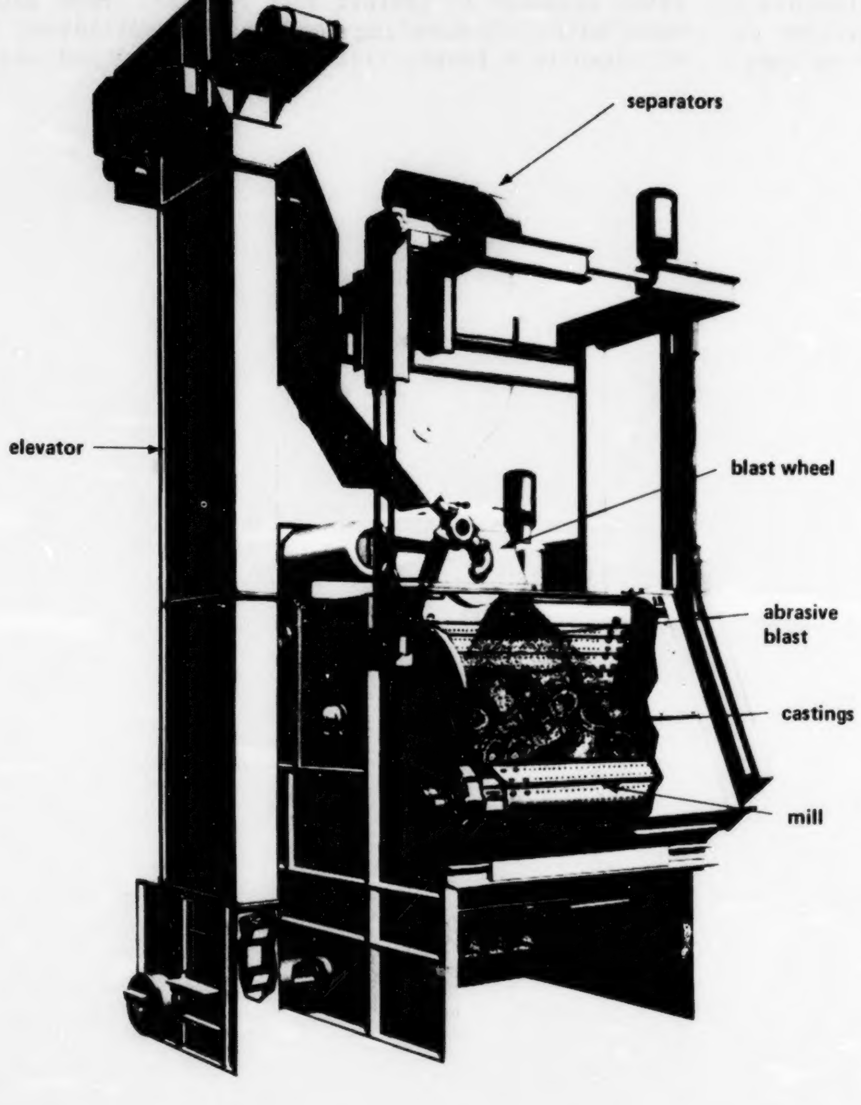
separators
elevator
blast wheel
abrasive blast
castings
mill

Figure 2-27. Abrasive blast cleaning unit.[20]

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More commonly, sand falls through the shakeout floor. At this level the metal is separated from the sand on a drum separator. The sand is then aerated and cooled and transferred by conveyors and bucket elevators to sand hoppers located above the mullers. Figure 2-28 shows a modern high volume sand system. This particular system was modified to use the Schumacher system to decrease emissions. In this system damp sand is introduced into the stream immediately after shakeout to inhibit dust release. Most sand handling systems use common materials handling hooding and ventilation systems, and the exhaust is directed to a fabric filter or low energy wet scrubber.

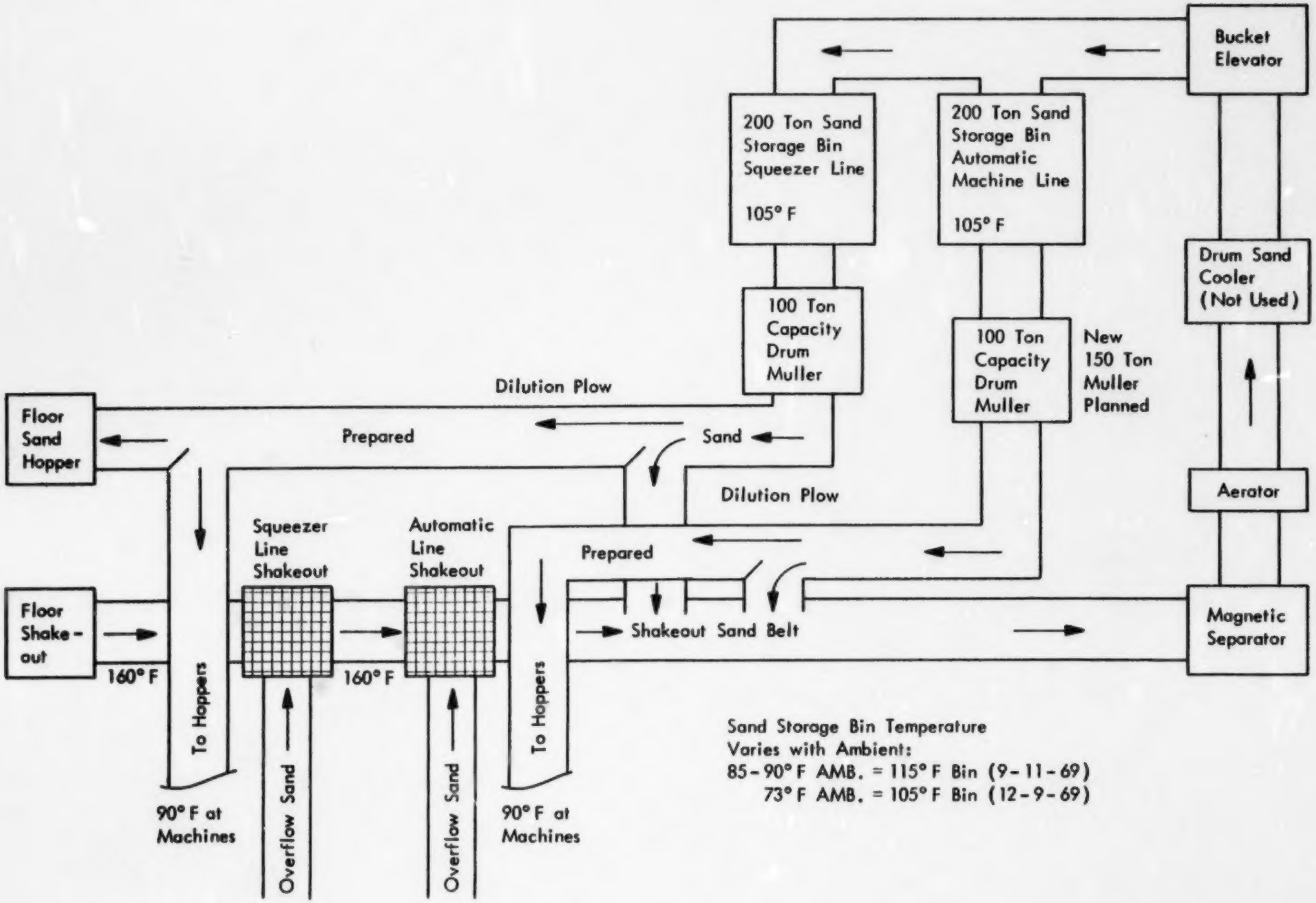
Bucket Elevator
200 Ton Sand Storage Bin Squeezer Line 105° F
200 Ton Sand Storage Bin Automatic Machine Line 105° F
Drum Sand Cooler (Not Used)
100 Ton Capacity Drum Muller
100 Ton Capacity Drum Muller
New 150 Ton Muller Planned
Dilution Plow
Floor Sand Hopper
Prepared
Sand
Dilution Plow
Aerator
Squeezer Line Shakeout
Automatic Line Shakeout
Prepared
Floor Shake-out
Shakeout Sand Belt
Magnetic Separator
160° F
To Hoppers
160° F
To Hoppers
Sand Storage Bin Temperature
Varies with Ambient:
85-90° F AMB. = 115° F Bin (9-11-69)
73° F AMB. = 105° F Bin (12-9-69)
90° F at Machines
Overflow Sand
Overflow Sand
90° F at Machines

Figure 2-28. A high volume sand handling system.[22]

SECTION 3.0

FOUNDRY EMISSION PROBLEMS AND CAUSES

3.1 INTRODUCTION

Ferrous foundries utilize a variety of processes. The specific processes used vary with the size and type of foundry. A fully mechanized modern foundry has most of the processes discussed in the foregoing section, while a small jobber foundry may have very few processes (melting and casting only).

Emission problems in foundries also vary from foundry to foundry. In a well controlled, large, modern foundry one can expect to find fewer emission problems than in small jobber foundries. In foundries that have properly designed control systems, emission problems can be related to one of the following causes:

- Poor operating practices.
- Poor maintenance of process and emission control equipment.
- Poor housekeeping.

This section discusses emission problems by process. The processes included are raw material storage and charge preparation, mold and coremaking; metal melting (emissions from cupolas, electric arc furnaces, and electric induction furnaces), iron inoculation; pouring and cooling; shakeout, cleaning and finishing; sand handling; and other miscellaneous areas. Table 3-1 shows in detail various types of emissions from different metallurgical processes. The source numbers on Table 3-1 are keyed to numbers on Figure 3-1, a flow diagram of a representative ferrous foundry.

3.2 RAW MATERIAL STORAGE AND CHARGE PREPARATION AREA

The storage, handling, and charge preparation of a ferrous foundry's raw materials (scrap metal, coke, fluxing agents) produces emissions in a variety of ways. The open storage of raw materials over time may result in the disintegration of these materials from the action of the sun, rain, and repeated freezing and thawing. Ferrous scrap rusts rapidly. Subsequent handling of these materials causes fugitive emissions around the storage and preparation area. When some of these emissions are carried away from foundry properties by wind or vehicular traffic, they become a nuisance problem. Visual observation of cupola plumes indicates that the degradation of coke and limestone also affects those emissions, although specific test data are not available to relate emissions from cupola to coke, limestone, and scrap quality.

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TABLE 3-1. EMISSIONS FROM METALLURGICAL PROCESSES, INDUSTRY: GRAY IRON FOUNDRY [15]

Source No.	Source identification	Particulates	Sulfur oxides	Carbon monoxide	Nitrogen oxides	Hydrogen sulfide	Metal fumes
	Limestone Handling						
1	Limestone unloading	X					
2	Limestone to storage	X					
3	Limestone storage	X					
4	Limestone to cupola furnace	X					
	Coke Handling						
5	Coke unloading	X					
6	Coke to storage	X					
7	Coke storage pile	X					
8	Coke to cupola furnace	X					
	Pig and Scrap Iron Handling						
9	Pig and scrap iron unloading	X					
10	Pig and scrap iron pile	X					
11	Pig and scrap iron furnace	X					
12	Cupola Furnace	1	X	X	X		X
13	Electric Arc Furnace	X		X			X
14	Induction Furnace	X		X			X
15	Ductile Iron Innoculation	X					

(continued)

TABLE 3-1. (continued)

Source No.	Source identification	Particulates	Sulfur oxides	Carbon monoxide	Nitrogen oxides	Hydrogen sulfide	Metal fumes
	Casting						
17	Casting shakeout	X					
18	Return sand to mold making	X					
19	Cooling and cleaning	X					
20	Finishing						
21	Castings loading (shipping)						
	Mold Making						
22	Mold binder unloading						
23	Mold binder storage						
24	Sand unloading	X					
25	Sand storage	X					
26	Sand to mix	X					
27	Mold mix	X					
28	Mold molding	X					
29	Spill sand return to mold mix	X					
	Core Making						
30	Core sand unloading	X					
31	Core sand unloading	X					
32	Core sand to core mix	X					
33	Core binder unloading	X					
34	Core binder storage	X					
35	Core binder to core mix	X					
36	Core mix	X					
37	Core molding	X					
38	Core baking	X	X	X			
	Pollution Control						
39	Baghouse dust	X					

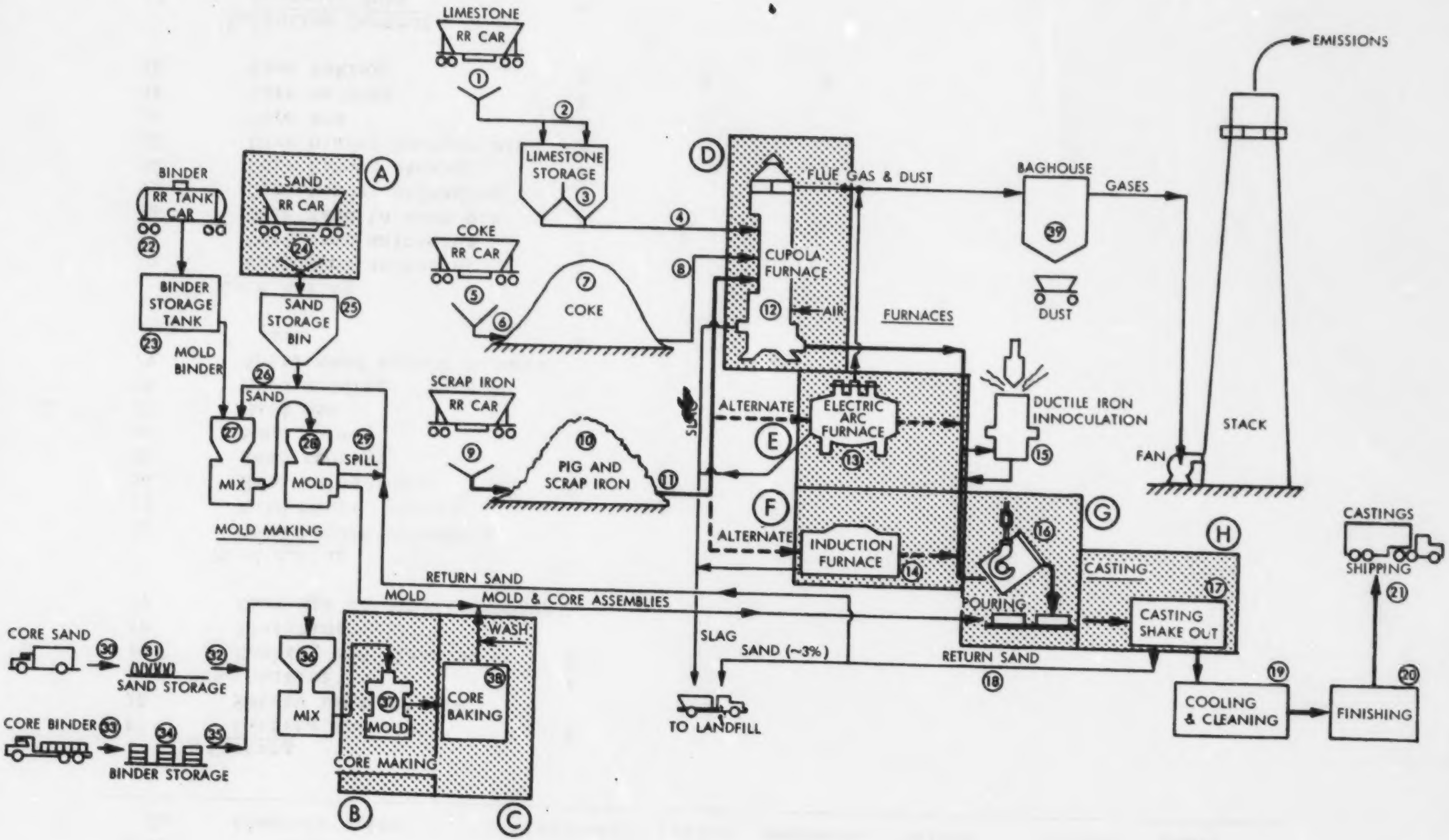

LIMESTONE
RR CAR
①
②
LIMESTONE STORAGE
③
④
BINDER
RR TANK CAR
㉒
BINDER STORAGE TANK
㉓
MOLD BINDER
SAND
RR CAR
㉔
Ⓐ
SAND STORAGE BIN
㉕
㉖
SAND
㉗
MIX
㉘
MOLD
㉙
SPILL
MOLD MAKING
COKE
RR CAR
⑤
⑥
⑦
COKE
⑧
SCRAP IRON
RR CAR
⑨
⑩
PIG AND SCRAP IRON
⑪
Ⓓ
FLUE GAS & DUST
CUPOLA FURNACE
⑫
AIR
BAGHOUSE
㉙
DUST
GASES
EMISSIONS
STACK
FAN
FURNACES
ALTERNATE
SLAG
ELECTRIC ARC FURNACE
⑬
Ⓔ
Ⓕ
ALTERNATE
INDUCTION FURNACE
⑭
DUCTILE IRON INNOCULATION
⑮
⑯
Ⓖ
POURING
Ⓗ
CASTING
⑰
CASTING SHAKE OUT
RETURN SAND
MOLD
MOLD & CORE ASSEMBLIES
SLAG
SAND (~3%)
TO LANDFILL
RETURN SAND
⑱
⑲
COOLING & CLEANING
⑳
FINISHING
㉑
CASTINGS
SHIPPING
CORE SAND
㉚
㉛
SAND STORAGE
㉜
CORE BINDER
㉝
㉞
BINDER STORAGE
㉟
㊱
MIX
㊲
MOLD
㊳
CORE BAKING
WASH
CORE MAKING
Ⓑ
Ⓒ

Figure 3-1. Flow diagram of representative ferrous foundry.15

The preparation of metallic charge materials includes breaking and cutting large scrap materials and removing cutting oil residue from machine shop turnings and borings in preparation for briquetting. The cutting of oily, painted, or other contaminated scrap causes excessive smoke and particulate emissions. Similar emission problems may exist in foundries where scrap is preheated before it is charged to an electric induction furnace.

These emission problems are seen more often in smaller, older foundries than in modern, larger foundries. The emissions from the former are considered a minor problem and more of a nuisance problem than a compliance problem.

3.3 MOLD AND CORE OPERATION

The only source of particulate emissions from mold and core operations is fugitive emissions during the transfer of dry materials such as clean sand, spent sand from the shakeout area, and the dry mixing of sand and binder. One especially vulnerable point in the operation is sand charging at the muller. Other emissions resulting from these operations are carbon monoxide and organic vapors (formaldehydes, amines, ammonia, and phenols) from the binders used in molding operation; such mixtures of organic vapors have a "typical foundry odor." Most foundries have good ventilation and a fresh air system to protect workers in these areas. Emission problems become noticeable when the hooding or exhaust system does not effectively capture the emissions or when the control device does not effectively remove pollutants from the emission-laden stream.

3.4 METAL MELTING

The greatest amount and heaviest concentration of emissions are generated in this area of a foundry, thus requiring control equipment on cupolas and some electric arc furnaces and electric induction furnaces.

3.4.1 Cupola

The cupola is the single largest source of emissions, emitting fumes, smoke, metallic dust, and gases. Several studies show that cupola emission rates are not significantly affected by the design of a furnace within the parameters established by current U.S. design practices. These parameters include the method of blast heating, top or side charging, charging door size and whether the opening is closed or open, the location of the gas takeoff above or below the door, or an open stack permitting the gases to escape out the top. In addition, no significant effect on emission rates was found for specific melting rates.[18]

Some factors do affect emissions. In general, if all other factors are equal, unlined cupolas have emission rates greater than lined cupolas. The use of briquettes also increases emissions.[18]

Acid-lined cupolas show a significant correlation between emissions and blast rate, expressed by the equation.[18]

$$E = 0.05 + 0.07B$$

where E = Particulate emissions (lb/ton melt)

B = Specific blast rate (SCFM 1 ft^2 furnace area)

A U.S. Department of Energy study of the effect of blast rate on cupola emissions shows that in seven of eight cases the blast rate had a significant relationship to emissions. Also, melting metal at a higher rate produces a higher loading of fine particles.[23]

Data from a Canadian Department of Energy, Mines and Resources study indicated that at least 40% and perhaps as much as 60% reduction in emissions was obtained from the use of screens and other precautions to limit the amount of loose sands, rust, and coke fines charged to the furnace. Since the cupola is kept under negative pressure for emission control purposes, charging is generally not a fugitive emission problem.[23,24]

Tapping a cupola is done in one of two ways. In the first case, the metal is tapped to a forehearth where slag is skimmed and then the iron is transferred into a ladle for pouring. In this case, the slag skimming and transfer into the ladle are minor sources of fine particulate emissions. In the second case, the metal is tapped directly to a ladle and the slag is skimmed from the ladle. This is also a minor source of fine particulate emissions.

Cupolas equipped with a takeoff for collecting emissions that are below the charge door will have a potential emissions problem during the burndown operation. Significant emissions may be released to the atmosphere through the charge door, unless some means were provided to physically seal off the stack between the charge door and the point of emissions takeoff.

If a cupola has correctly designed air pollution devices installed on it, typical emission problems usually result from incorrect operating practices or malfunctions of the control equipment.

3.4.2 Electric Arc Furnace

Emissions from the electric arc furnace (EAF) occur at five stages of the operation: charging, melting, backcharging, oxygen lancing (generally used only in steel foundries), and tapping.

In general, an EAF which is well-controlled (emissions controlled by direct shell evacuation, canopy hood, and fabric filter) will have very few emission problems. Excessive emissions will occur only if:

- Above-average dirty scrap with high oil content (turnings, chips, and borings from machine shops) is charged.

- The foundry increases production with short melting cycles; there is a direct relationship between the rate of emissions produced and the rapidity with which melting occurs.
- Inefficient capture takes place during charging, oxygen lancing, or tapping operations due to cross drafts through open doorways.
- Oxygen lancing is used to speed up the melting process and superheat the bath.

3.4.3 Electric Induction Furnace

No serious emission problem exists for induction melting of iron since in an electric induction furnace (EIF) the metal scrap used must be dry and free of oil. Many of these furnaces are uncontrolled. A fugitive emission problem may occur when oil residue on the scrap is burned off. This may require emission control equipment.

3.5 IRON INOCULATION

The emissions produced in the inoculation process are directly related to the level of inoculant (magnesium or similar alloying compound) recovery for the particular method used by the foundry. For example, in the pour-over method of inoculation only 20 to 30% inoculant recovery is obtained while the remainder of the inoculant is emitted as a fine oxide. This compares to the mold inoculation method where 80 to 90% inoculant recovery has been obtained; very few oxides are emitted.

3.6 POURING AND COOLING

The total emissions generated from pouring and cooling castings are not significant compared to total emissions from the foundry operations, although limited data indicate that they may be the most significant fugitive emissions. As the hot metal is poured into the mold, metallic fumes and products of combustion and decomposition of the binder systems are released to the foundry environment. The quantity of these emissions is related to mold size, mold composition, sand-to-metal ratio, pouring temperature, and pouring rate. These processes vary significantly among foundries. In mechanized foundries the molds are placed on a conveyor and moved to the pouring station and then moved to the cooling area where they are captured by a local exhaust system. In unmechanized foundries, this process takes place in large open areas in the foundry. The emissions are contained in a relatively high temperature, buoyant, moist stream and released to the foundry environment. The control of these emissions is difficult, and in most small foundries the emissions are uncontrolled.

3.7 SHAKEOUT, CLEANING, AND FINISHING

In general, emissions from these areas consist of dust from dried sand, organic residue from binders, steam, fine metallic particulates, iron oxide, and fumes. In most cases these emissions are controlled by local exhaust systems at the source. Exceptions are found in small foundries.

The major emission problem is caused by insufficient capture velocities in local exhaust systems. Airborne dust from handling and processing of materials also can add to inplant fugitive emissions. Most of these emissions are localized and are not released directly to the ambient air. For sources where local exhaust systems are used, most of the problems may be related to malfunctioning of a local exhaust system and air pollution control device.

3.8 SAND HANDLING SYSTEM

Dry sand from the shakeout goes through magnetic separation, cooling, and screening and is returned to storage or the muller. Each of these processing steps and conveyor transfer points is a potential source of fugitive particulate emissions. In most foundries, sand is moved by conveyor, usually an enclosed system, and some type of exhaust system is used at all transfer points. The major potential fugitive emissions problem from sand handling is malfunctioning control equipment or poor housekeeping. Many times, due to poor housekeeping, spillover sand and other materials become major sources of fugitive emissions within a plant area.

3.9 OTHER AREAS FOR POTENTIAL EMISSION PROBLEMS

3.9.1 Waste Handling

The primary waste materials produced at a foundry are slag from the melting operations and spent sand from molds and cores.

The slag, once skimmed off the molten metal, is solidified by air cooling or water quenching. Either cooling method can produce small amounts of sulfur dioxide, while hydrogen sulfide (H_2S) can be produced with water quenching.

Foundries that use green sand molds replace about 2 to 3% of total foundry sand daily to ensure proper sand quality. This spent sand is generally stored temporarily in either outdoor piles or hoppers. It is then transferred, along with slag, to a landfill for disposal. Potential for fugitive emissions exists during handling and transfer of the materials to the storage area, from wind erosion of outdoor storage piles, and, if covered transport vehicles are not used, during transfer to a landfill for final disposal.

3.9.2 Housekeeping

Many particulate fugitive emission problems in foundries are caused by poor housekeeping through reentrainment of dust by workers, mobile vehicles, machinery vibrations, and compressed air tools.

3.9.3 Routine Maintenance

Lack of routine maintenance of ventilation systems, local exhaust systems, ductwork, and air cleaning equipment also can contribute significantly to emission problems.

SECTION 4.0

INSPECTION PROCEDURES

It is relatively easy to demonstrate that a source is in violation of visible emissions (VE) or permit requirements, but not all inspections are this straightforward. Violations of standards regulating grain loading, process weight, fuel composition, or gaseous contaminants are more difficult to demonstrate and require greater effort. Compliance determinations in these cases are made only after sufficient information has been gathered on the operation and maintenance of the process and control equipment. The role of field inspectors is to obtain this information or to identify possible indicators that the source is out of compliance or will be out of compliance in the near future.

After receiving the inspection report from the field inspector, a staff engineer may require further fuel and material sampling, operational data, or special stack tests to show whether or not the source is in continuing compliance through all ranges of its operation. In some cases the field inspector may be the person who requires further information.

In the following subsections of this guide, the inspection procedures and checklists for typical processes and control equipment found in ferrous foundries are discussed. Inspections are described step by step, including what information the inspector should note and the reasons behind the required information. The checklists for various types of equipment are found in Appendix B.

4.1 PREINSPECTION PROCEDURES

The following paragraphs suggest preinspection procedures. They are intended as general guidelines and are not meant to supersede procedures that may have already been established by an agency.

4.1.1 File Review

The first step in preparing for an inspection is to review information in your agency's file. You should review the types of processes and control equipment you will be inspecting, previous reports from other inspections, past conditions of noncompliance, history of malfunctions, citizen's complaints, and other relevant information which will give you some background on the source's continuing compliance efforts. During this file review, you can complete the "Cover Sheet for Process and Control Equipment Checklist" (see Appendix B).

In the agency file, you may also find data on the normal range of operating conditions for processes and control equipment. This baseline data should be compared to data collected during the actual inspection. For example, if the melt rate of the cupola is higher than the melt rate in the original file, the cupola may be in violation of mass emission regulations.

4.1.2 Announcement of Inspection

If the inspection is to be announced, the inspector should inform the source a few days to a week in advance so the proper plant personnel will be available as escort during the inspection. The plant should be inspected when all or most of the operations are running to avoid the necessity for additional visits to the plant.

4.1.3 Safety and Pre-Plant Entry

A hardhat, safety glasses, safety shoes, and earplugs are the most likely safety equipment items you will need for the inspection. Suitable clothing should be worn and an OSHA-approved dust mask should be available. See Section 5 for detailed discussion of equipment needs.

If it is possible before entry, drive around the perimeter of the plant property to observe any visible emissions, fugitive emissions, or odor problems. If you notice any violations, take VE readings from an appropriate position. If your agency provides a camera, then you should take pictures. In some cases you might have to enter the plant property to take VE readings. If so, you may have to get permission from the source to be on plant property.

4.1.4 Plant Entry

When you arrive at the gate or front office of the plant, introduce yourself, show proper identification, and request to see the responsible plant official. Follow your agency's instructions regarding the signing of any forms that limit the plant's liability for your safety or that restrict the scope of your inspection.

If this is an unannounced inspection and for some reason the plant denies your entry to all or part of the facility, note the reasons for refusal, the name and title of the plant official responsible for the refusal, and the precise time of the refusal. Notify your supervisor by telephone immediately, and let your agency's legal staff handle the matter.

4.1.5 Preinspection Meeting

Before starting an inspection you should meet briefly with plant officials to discuss the following points:

- Purpose of the inspection.

- Any hazardous areas.

- Process(es) and control equipment to be inspected.
- Any changes in responsible officials since the last inspection.
- Any changes or modifications in plant operations since the last inspection.
- Current data on production including raw material and process weight rate and that day's melting rate.
- Treatment of confidential data.

Avoid requesting redundant data from the plant officials. However, be sure to request all information that is essential to your inspection. Know exactly what you want to inspect to avoid wasting your time and that of the plant personnel.

4.2 PROCESS AND CONTROL EQUIPMENT INSPECTION PROCEDURES

The typical ferrous foundry has a variety of operations which may be sources of particulate and gaseous emissions. For the following discussion foundry operations are divided into melting operations and nonmelting operations.

A typical inspection is performed in four steps:

- Stack and roof observations;
- Data gathering in the instrument control room;
- Inspection of control equipment; and
- Inspection of process equipment and local exhaust systems.

The steps will vary depending upon the process and control equipment, but, in general, the checklists are set up in the above order.

Appendix B contains six checklists which cover various combinations of typical process and control equipment used in foundries. Checklists for melting operations cover processes and control equipment, while checklists for nonmelting operations cover only local exhaust systems and control equipment. Process operating conditions do not typically cause emission problems in nonmelting operations.

Before you start the inspection, you should have completed "Cover Sheet for Process and Control Equipment Checklist." To save inspection time, this can be completed during your file review at the agency. Clearly identify facility name and address, inspection date and time, type of process, process ID, and control equipment ID. Make sure you identify all processes if the control equipment serves more than one process. Equipment ID is important when a facility has more than one process of similar type; e.g., a large automobile engine block manufacturer may have five to seven cupolas side by side, and the emissions may be controlled by only two or three scrubbers.

4.2.1 Melting Operations

In general, there are three typical process-control equipment combinations in foundries: (a) cupola with high energy scrubber; (b) cupola with gas cooling system, fabric filter; and (c) electric arc furnace or electric induction furnace, fabric filter.

One area common to all these melting operations is the charge preparation area. See Appendix B for the checklist covering the charge preparation area.

4.2.1.1 Inspection of Charge Preparation Area (Checklist I)--
During the preinspection meeting with plant officials, you should get information on raw material and process weight rate. Compare these numbers with the numbers in the foundry's original permit application or the information in the file. Changes in composition of the charge will affect the emissions.

During the walkthrough of the charge preparation area:

- Check if the scrap is dirty (oily, rusted, fine matter), and note if any charge preparation is done, for example, cutting big pieces of scrap, burning off of oil from scrap, or any screening.
- Check if raw materials are stored in an enclosed building or outdoors.
- Observe charge loading. Excessive dust dumped with other raw materials will increase emissions from melting equipment.
- Check how charges are weighed. If weight is approximated, find out how the melting rate or process weight is estimated because compliance with process weight regulations could be affected.

4.2.1.2 Inspection of Cupola with High Energy Scrubber (Checklist II)--
During the preinspection meeting with plant officials, you should get information on the melting rate. Make sure the number you are told is the actual melting rate of that day and not the number submitted previously to the agency. Ask for the logbook or plant records to verify the melting rate.

During the walkthrough:

- Request to be taken to the roof if possible, or find a location where you can observe the stacks.

- Look for any VE violations or fugitive emissions.

- Look for leakage of gases from the cupola top.

Next, visit the cupola control panel. In many foundries the instrument panel for the scrubber is located in the same room; in some foundries, however, controls for furnace and control equipment are in different places. In the latter case, you will have to visit both areas.

- Note the data requested in the checklists.

- Check when the monitoring instruments were calibrated the last time.

- If the instruments are not functioning, find out and note the reasons.

Next, visit the scrubber system. A typical type of high energy scrubber used in a foundry is the Venturi scrubber.

- Inspect externally the whole scrubber housing, associated ductwork, fan housing, and pumps for corrosion and leakage.

Any air infiltration will reduce operating pressure of the system and affect the efficiency of the control system.

Since high energy scrubbers operate with high pressure (40 to 70 in. wg.) it is not possible to observe the scrubber internally when the system is operating. If the scrubber is equipped with portholes through which the spraying nozzles or sump area can be seen, then:

- Check whether scrubbing liquid is being sprayed with proper pressure. Low pressure results in an increase in the water spray droplet size and results in reduced collection efficiency.

- Look for plugged or worn nozzles or buildup of scrubbing liquid in the sump (see Figure 4-1). In most cases you will have to depend upon the data gathered at the instrument panel. A very high water pressure indicates a plugged nozzle which should be replaced. A below average flow rate of scrubbing liquid indicates pumps are not operating efficiently or that the recirculated liquid contains suspended solids. If the pump motor is equipped with an ammeter, then a below average ampere reading indicates plugging of nozzles or spray bars. It also can indicate pump wear or plugging of the suction line. An increase in the ampere reading indicates holes in the spray bar or missing nozzles.

- Check the fan system for excessive vibration and audible belt slippage noise. Causes of fan vibration can be material buildup on fan blades, cracks in the fan blades or wheel, holes due to corrosion in the fan housing, or open access doors (Figures 4-2 through 4-4). Fan vibration will eventually cause a breakdown and severe mechanical damage that can result in a malfunctioning control system.

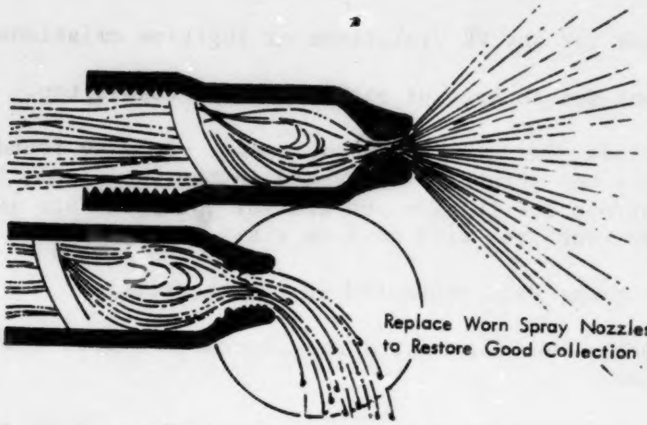


Figure 4-1. Reduction in spraying action of worn nozzle.

Replace Worn Spray Nozzles - to Restore Good Collection Efficiency

WORN FAN HOUSING

Holes or Cracks in Housing Starve Air from the System

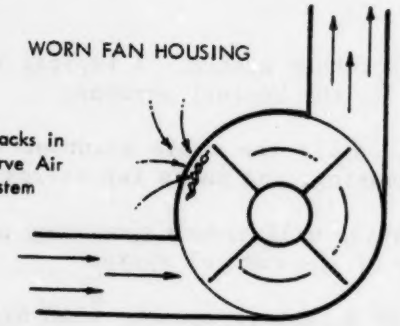


Figure 4-2

EXCESSIVE FAN VIBRATION

Excessive Vibration is Usually Caused by Worn Impeller. Replace or Repair Promptly - FLYING BLADES ARE LETHAL. Use Qualified Personnel Only.

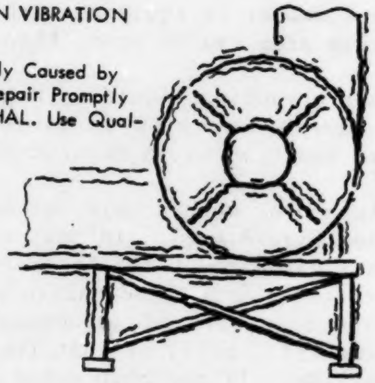


Figure 4-3

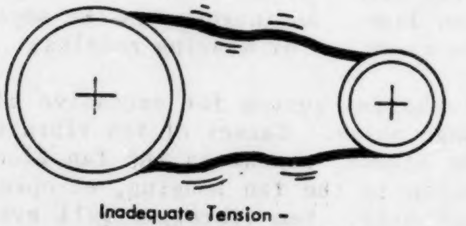


Figure 4-4

Inadequate Tension - Causes Belt Slippage and Wear

Figures 4-2 - 4-4. Typical fan problems.

Source: The Maintenance and Operation of Exhaust Systems in the Hot Mix Plant, Information Series 52A, National Asphalt Paving Association.

Last, observe the cupola operation.

- Check for fugitive emissions at the charge door during the charging operation.

- Check if afterburners are operating. These burners burn off carbon monoxide and other oily organic materials. Thus, they help in complying with opacity regulations and also prevent explosions in the gas cleaning system. Further, they reduce problems caused by condensation of organic materials in the primary control device.

- Check that the cupola top remains closed at all times during operation. If you find it open, find out the reason.

- Check if the cupola system is equipped with a control equipment bypass system, and note the amount of time control equipment is bypassed (check plant records). Discuss excessive malfunction problems with plant personnel. If data from the instruments positively indicate problems with the scrubbers, set up a time with plant personnel to inspect the scrubbers internally.

- Follow the steps in the checklist.

- If time permits, observe the foundry's start-up and shutdown practices.

4.2.1.3 Inspection of Cupola with Gas Cooling System, Fabric Filter (Checklist III)--

The initial steps of stack observation and data collection from the control room are the same as those discussed above for the cupola with high energy scrubber. After noting the data required (see checklist) from the cupola control room and/or monitoring instruments for the control equipment:

- Inspect the gas cooling system. The three systems most commonly used in foundries are: cooling by convection columns, by dilution of exhaust gases by air, or by spray towers. Although the checklist for the gas cooling system is primarily written for spray towers, a common but important parameter for any cooling system is the exit temperature of the gases which enter the fabric filter. This temperature should be sufficiently low to prevent damage to the bags in the fabric filter. At the same time, to prevent condensation on bags or other fabric filter components, the temperature should not be lower than the dew point of the entering gases.

- Consider the various items in the checklist and whether the indicators show that the cooling system is functioning properly or potential problems exist.

After checking the gas cooling system:

- Examine the fabric filter system externally for corrosion of the housing, weld seam gaps, and holes. This type of damage will cause external air infiltration, which reduces operating pressure, causes condensation on internal surfaces of the fabric filter housing bags, and promotes bag blinding and corrosion.

- Check the proper operation of cleaning cycles by making visual observations; listening for sound from movement of solenoid valves, noise of air puffs, or a shaker mechanism in operation; and noting pressure gauges. Pressure gauges in multicompartment fabric filters will show lower pressure in the compartment that is going through a cleaning cycle.

- Observe the discharge of solids from screw conveyors or hoppers. An irregular or erratic discharge indicates solids buildup or bridging in the hopper. Only an internal inspection will reveal the definite cause.

- Check the fan system for excessive vibration and audible belt slippage noise.

- Compare data noted from the instruments with the average values (available from the agency's files or fabric filter manufacturers). Excessive pressure drop across the fabric filter indicates bag blinding, cleaning system not operating properly, insufficient cleaning cycle time, or solids removal system not operating properly. If the pressure drop across the fabric filter is below average, bag tears or loose or missing bags are indicated.

If during the external inspection you find abnormal values for operating parameters compared to average values, then an internal inspection may be warranted. With compartmentalized fabric filters you may be able to perform an internal inspection while the fabric filter is operating. This should be done only if necessary and a self-contained respirator should be worn at all times inside the fabric filter. Otherwise you may have to reschedule an internal inspection when the filter is not operating.

During an internal inspection:

- Make sure you take all safety precautions to guard against heat, toxic gases, and low oxygen levels. A plant official should accompany you on the internal inspection. Note: Never conduct internal inspections alone.

- Check that the clean side of the fabric filter is clean; if it is not, there are definitely broken or loose bags.

- Check for material deposited on bags or on the floor near the bottom of bags.

- Check the condition of the bags. It will indicate improper operations; e.g., burn spots on bags indicate insufficient cooling of exhaust gases entering the fabric filter or that the wear plate is worn out and gases are entering at high velocity. Any dust buildup or bridging in the hopper or fabric filter indicates air and moisture leaks in the fabric filter or that the solids removal system is not functioning properly.

- If possible, check the high temperature alarm system and the fabric filter bypass system. If the cooling system fails and the alarm system or the bypass system is not functioning, the filter can be damaged severely.

Last, observe the cupola operation.

- Check for fugitive emissions at the charge door during the charging operation.
- Check if afterburners are operating. These burners burn off carbon monoxide and other oily organic materials. Thus, they help in complying with opacity regulations and also prevent explosions in the gas cleaning system. Further, they reduce problems caused by condensation of organic materials in the primary control device.
- Check that the cupola top remains closed at all times during operation. If you find it open, then find out the reason.
- Check if the cupola system is equipped with a control equipment bypass system, and note the amount of time control equipment is bypassed (check plant records).
- Discuss excessive malfunction problems with plant personnel. If data from the instruments positively indicate problems with the scrubbers, set up a time with plant personnel to inspect the scrubbers internally.
- Follow the steps in the checklist.
- If time permits, observe the foundry's start-up and shutdown practices. Obtain process related data (see checklist) prior to the inspection and observe during the inspection.

4.2.1.4 Inspection of Electric Arc Furnace or Electric Induction Furnace, Fabric Filter (Checklist IV)--

Since the basic steps to inspect the electric arc furnace (EAF) and the electric induction furnace (EIF) are the same, one checklist is sufficient. In general, only clean scrap is melted in the EIF; thus, there are very few emissions. You may find that an EIF has no controls at all.

For the initial inspection steps of observing visible and fugitive emissions:

- Request to be taken to the roof if possible, or find a location where you can observe the stacks.

- Look for any VE violations or fugitive emissions.

Next is the inspection of the control equipment and fabric filter. The majority of the emissions from the EAF and EIF are captured through a side draft or canopy hood. Captured emissions are then taken to the fabric filter. Since large amounts of air are exhausted with the emissions, a gas cooling system is not needed.

For inspection of the fabric filter the reader should refer to subsection 4.2.1.3.

During the inspection of the EAF and EIF, you should observe all operations: charging, tapping, back-charging, and melting.

- Look for fugitive emissions.

- Check if the canopy hood or any other type of hood is capturing emissions properly. In many instances, cross-drafts caused by open windows and doors will deflect emissions away from the hood. Many times, the charge is preheated in the EIF and may cause fugitive emissions.

- Check the preheating of the charge buckets or conveyors for emission problems.

4.2.2 Nonmelting Operations

The nonmelting foundry operations (pouring and cooling, shakeout, cleaning, and sand handling) which are sources of particulate and organic vapors can be classified as fugitive emissions sources. They are so defined because, in the absence of auxiliary ventilation systems, the emissions enter the foundry environment and are exhausted to ambient air through doors, windows, roof monitors, and exhaust vents rather than through a confined stack.

In medium to large mechanized foundries with auxiliary ventilation systems, problems may be due to malfunctions of the exhaust ventilation system or operation and maintenance of the control equipment or ductwork. In most foundries, these emissions are controlled by low energy scrubbers or mechanical collectors (cyclone, multiclone).

As you will note, the checklist for nonmelting operations is for local exhaust systems and control equipment only, not for processes. Primarily, therefore, you will be checking the exhaust system (emission pickup points, hoods, ductwork) and the related control equipment. However, you should identify any other fugitive emissions that are occurring from the operations.

4.2.2.1 Local Exhaust System with Low Energy Scrubber (Checklist V)--The first steps in inspecting any of the nonmelting operations are:

- Go up to the roof, if possible.
- Look for any visible emissions from stacks or fugitive emissions through ventilation fans.
- Make VE readings if needed.
- If you see a large amount of particulate (e.g., sand) on the roof, inquire about any regular cleaning program. Such particulates can become windblown and cause fugitive emission problems.

The next step is:

- Visit the control equipment area and check the scrubber system visually. This system will be much smaller and less complex to inspect than a scrubber system on melting equipment. Most of the time this type of scrubber will not have many monitoring instruments. If there are pressure gauges or a flow meter, they will usually be located very close to the control system.
- Note the data required in the checklist.
- Make visual observation, through the access doors or portholes, of the scrubbing liquid spraying system for plugged or missing spray nozzles and buildup of scrubbing liquid in the sump.
- Check the fan system for vibration and audible belt slippage. If you notice a problem, then follow other steps in the checklist to find the causes. Causes of fan vibration can be material buildup on fan blades, cracks in the fan blades or wheel, holes due to corrosion in the fan housing, or open access doors. Fan vibration will eventually cause a breakdown and severe mechanical damage that can result in a malfunctioning control system.

Next, visit the process equipment area to observe the local exhaust system. Usually, this system consists of a hood and exhaust ductwork, and the emissions are captured by the hood and then transferred through the exhaust ductwork to the control equipment. Often there are several hoods collecting different types of emissions, and these hoods are then connected to one control device.

- Check to see if emissions are being captured adequately by the hood. Emissions or exhaust gases may be deflected from the hood because of insufficient capture velocities, improper location of the hood, or the presence of cross-drafts (caused by open windows, a large opening in the building, or open doors) or thermal drafts. Large amounts of dust in the ductwork, which plug the exhaust system, can result in low flow and poor capture. Common emission problems at more than one nonmelting operation may indicate poor operation and maintenance of the control system.

4.2.2.2 Local Exhaust System with Mechanical Collectors (Checklist VI)--

Initial steps in the inspection of this type of system will be the same as those discussed above in subsection 4.2.2.1. Perform all external checks first.

Most mechanical collectors are structurally unified with almost no moving parts except the solids removal system. Thus, they require very little maintenance. The first problem associated with mechanical collectors is holes due to corrosion and wear caused by abrasive dust or a high dust loading. The second problem is associated with the buildup of dust in the exhaust ductwork and inside walls of the collector. Holes due to corrosion or wear in the body of the collector and/or ducts allow outside air to enter, displacing exhaust gases. This reduces the capacity of exhaust hoods and affects their collection efficiency (see Figure 4-5).

If visible emissions are observed from the gas outlet tube, then an internal inspection may be needed.

- Take necessary safety precautions before you perform an internal inspection. (See Section 5 for detailed discussion of possible hazards.) An internal inspection is done mostly by visual observations.

- Check flop gates, double-tipping gates, or rotary airlocks for air leakage and wear (see Figures 4-6 and 4-7). If the particulate discharge valve fails or the collection hopper is clogged, then material may accumulate in the cyclone to the point that it ceases to function (Figure 4-8).

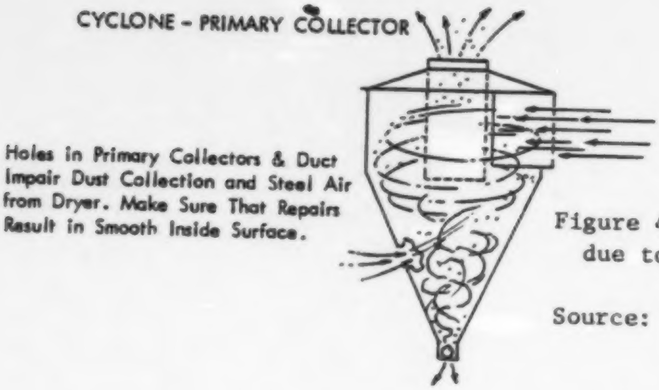

CYCLONE - PRIMARY COLLECTOR
Holes in Primary Collectors & Duct Impair Dust Collection and Steel Air from Dryer. Make Sure That Repairs Result in Smooth Inside Surface.

Figure 4-5. Disturbance in airflow due to holes in cyclone.

Source: The Operation and Maintenance of Exhaust Systems in the Hot Mix Plant, Information Series 52A, National Asphalt Paving Association.

Figure 4-6

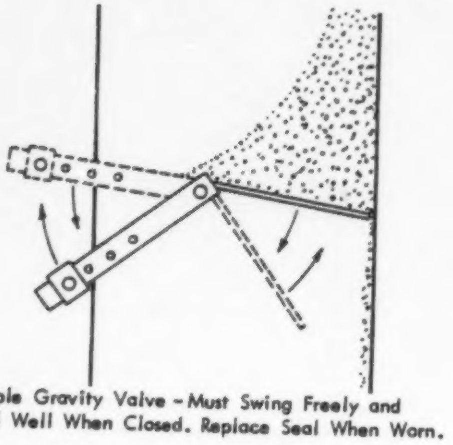

Simple Gravity Valve - Must Swing Freely and Seal Well When Closed. Replace Seal When Worn.

Figure 4-7

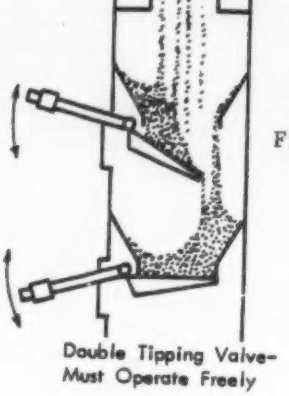
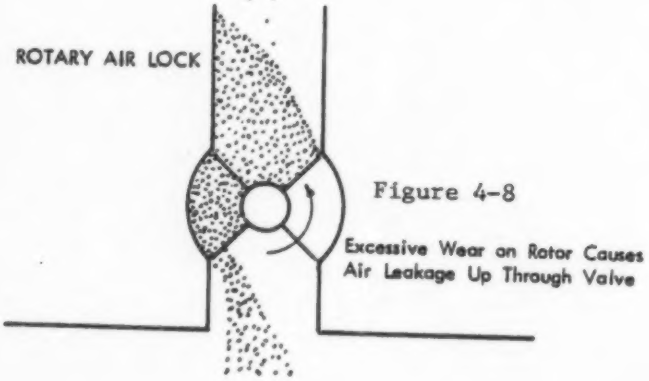

Double Tipping Valve-Must Operate Freely

Figure 4-8


ROTARY AIR LOCK
Excessive Wear on Rotor Causes Air Leakage Up Through Valve

Figures 4-6 - 4-8. Various types of valve related problems found in mechanical collectors.

SECTION 5.0

HEALTH AND SAFETY GUIDELINES FOR FOUNDRY INSPECTORS[25,26]

5.1 INTRODUCTION

There are several measures an inspector should consider taking in order to protect his or her personal safety and health when conducting foundry inspections. Appropriate protective equipment should be worn, and the inspector should be familiar with potential safety or health problems before entering a foundry.

The personal protective equipment that should be considered prior to entry includes a hardhat, safety glasses, safety shoes, hearing protection, and protective work clothing (e.g., heavy long-sleeved shirt and jeans). Loose clothing which can get caught in machinery is not suitable. The need for these safety items should be discussed with foundry personnel.

The inspector should also determine during the preinspection conference with foundry personnel if there are any areas that have restricted access, are particularly hazardous, or if there are any specific precautions to be taken in any area of the foundry. The inspector should always be accompanied by an employee of the plant who is familiar with the plant's operation. Someone should be assigned to accompany the inspector.

5.2 FOUNDRY PROCESSES AND ASSOCIATED SAFETY AND HEALTH HAZARDS

Although no two foundries are alike, they all basically melt metals and cast them into useful shapes called castings. Therefore, the processes are similar. The basic foundry processes and hazards associated with them are discussed in this section. These processes are:

- Sand preparation
- Core making
- Molding
- Melting and pouring
- Shakeout
- Cleaning of castings

5.2.1 Sand Preparation

The major potential health hazard associated with the preparation of sand for coremaking and molding is exposure to airborne dusts. Most foundry sands contain crystalline-free silica which, if breathed in excessive amounts, can result in silicosis. Proper use of a NIOSH- or MESA-approved single use dust mask or a dust respirator with a mechanical filter should provide adequate protection to inspectors who are transiently exposed to high dust levels.

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5.2.2 Coremaking, Molding, Melting, and Pouring Operations

Potential exposure to mineral and silica dusts occurs in the core room and is associated with automatic core molding, core sand mulling, and core finishing. Exposure to resins, solvents, and chemicals also presents potential hazards. Many of these resins, solvents, and chemicals are potential skin and respiratory irritants, and skin contact should be avoided. If the inspector plans to spend considerable time (2 to 8 hr) in the area, proper OSHA-recommended respirators should be worn. The physical hazards which might be present include noise and nonionizing microwave radiation. Approved earplugs or earmuffs and protective clothing should be worn.

If the inspector intends to spend considerable time (2 to 8 hr) in the melting and pouring area, hazards posed by hot environments should be considered, and appropriate measures such as protective clothing or staying behind a heat shield (highly reflective material) should be considered. The inspector should be aware of the potential presence of carbon monoxide around the top of the cupola and at the tapping station. Appropriate respiratory protection is recommended. Core binders and additives thoroughly decompose during pouring and molding operations and can pose potential health hazards.

5.2.3 Shakeout, Cleaning, and Grinding Operations

The separation of a casting from the sand (shakeout) and the core from certain castings results in potential exposure to silica dust, metal dust, and fumes. As in many other areas of the foundry, noise is a potential hazard in the shakeout, cleaning, and grinding area. Approved earplugs or earmuffs should be worn. Metallic fumes such as iron oxide, zinc oxide, lead, silica dust, and metal dust can result from chipping, rough grinding, sand and shot blasting, finish grinding, sprue cutting, and other cleaning operations. Proper respiratory protection is recommended.

5.2.4 Other Miscellaneous Operations

Ionizing radiation may present a hazard if X rays are used to inspect large castings. Potential exposure can be avoided by maintaining a safe distance from any energized or seal source. Nonionizing radiation (ultraviolet and infrared) is given off during burning operations. Use of special dark tinted glasses and protective clothing (long sleeves and gloves) can help prevent exposure to these potential hazards.

SECTION 6.0

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APPENDIX A

GLOSSARY OF TERMS USED IN FOUNDRY INDUSTRY

ACFM - Actual cubic feet per minute; refers to the volume of gas at the prevailing temperature and pressure.

Acid Lining - A refractory furnace lining made essentially of silica.

Additive - A substance added to another in relatively small amounts to impart or improve desirable qualities, or suppress undesirable qualities.

Aerosol - Small liquid or solid particles dispersed in a gaseous medium (dust, fog, smoke, for example).

Afterburner - A device for burning combustible materials that were not oxidized in an initial burning process.

Agglomeration - Gathering together of small particles into larger particles.

Air Furnace - A reverberatory-type furnace in which metal is melted by heat from fuel burning at one end of the hearth, passing over the bath toward the stack at the other end.

Anneal - A heat treatment which usually involves a slow cooling for the purpose of altering mechanical or physical properties of the metal, particularly to reduce hardness.

Back Charge - Second charge added to the molten initial charge as soon as sufficient volume is available in the furnace. Back charging produces a violent eruption of emissions.

Baked Core - A core which has been heated to produce the desired physical properties attainable from its oxidizing or thermal setting binders.

Basic Lining - The inner lining and bottom of a melting furnace composed of materials that have a basic reaction in the melting process; usually either crushed burned dolomite, magnesite, magnesite bricks, or basic slag.

Bed - Initial charge of fuel in a cupola upon which the melting is started.

Bentonite Clay - A widely distributed, peculiar type of clay which is considered to be the result of denitrification and chemical alteration of the glassy particles of volcanic ash or turf. Used in foundry to bond sand.

Binder(s) - Material to hold the grains of sand together in molds or cores. May be cereal or clay, resin, pitch, etc.

Blast - Air driven into the cupola furnace for combustion of fuel.

Blast Volume - The volume of air introduced into the cupola for the burning of fuel. This volume governs the melting rate of the cupola.

Blind Filter Bags - A buildup of water, oil, or similar materials on filter bags that restricts the flow of gases through the filter.

Borings - Metal in chip form resulting from machining operations.

Briquette - Block of various shapes formed of finely divided materials by incorporation of a binder, by pressure, or by both. Materials maybe ferroalloys, metal borings or chips, silicon carbide, coke breeze, etc.

Burden - A collective term of the component parts of the metal charge for a cupola melt.

Burned Sand - Sand in which the binder or bond has been removed or impaired by contact with molten metal.

Canopy Hood - A metal hood over a furnace for collecting gases being exhausted into the atmosphere surrounding the furnace.

Cantilever Hood - A counterbalanced hood over a furnace that can be folded out of the way for charging and pouring the furnace.

Capture Velocity - The air velocity at any point in front of a hood or at a hood's opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow toward a hood.

Cast Iron - A generic term for the family of casting alloys composed of iron, carbon, and silicon in which the carbon is present in excess of the amount that can be retained in solid solution in the austenite that exists in the alloy at the eutectic temperature. This family of ferrous alloys includes chilled iron, pig iron, gray cast iron, white cast iron, mottled cast iron, malleable cast iron, and ductile iron.

Cereal	- A binder used in core mixtures and molding sands, derived principally from corn flour.
Channel Induction Furnace	- In this type of induction furnace, the metal charge surrounds the transformer core, thereby forming a loop or channel.
Charge	- The total ore, ingot, metal, pig iron, scrap, limestone, etc., introduced into a melting furnace for the production of a single heat.
Charging Door	- An opening in the cupola or furnace through which the charges are introduced.
Coke	- The product resulting from the destructive distillation of suitable coal in which the volatiles have been driven off by heating in the absence of air; used as a fuel in cupola furnaces.
Coke Breeze	- Fines from coke screenings.
Cold Box Molding	- A core making or molding process in which cold set binders (urethane resins) are used and cure (hardened) by passing a catalyst gas [usually triethylamine (TEA) or dimethyl ethylamine (DMEA)] through the mold.
Control at the Source	- Exhaust capture close enough to the point of generation of air contaminants to prevent the contaminants from entering the general atmosphere.
Convection	- The motion resulting in a fluid from the differences in density and the action of gravity due to temperature differences in one part of the fluid and another. The motion of the fluid results in a transfer of heat from one part to another.
Cope	- The upper or topmost section of a flask, mold, or pattern.
Core	- A separate part of the mold which forms cavities and openings in castings which are not possible with a pattern alone. Cores are usually made of a different sand from that used in the mold and are generally baked or set by a combination of resins.
Core Binder	- Any material used to hold the grains of core sand together.

Core Blower	A machine for making cores by blowing sand into the core box by means of compressed air.
Coreless Induction Furnace	In this type of induction furnace, the metal heated by both the core and secondary coil. Furnace coils are water cooled to prevent heat damage.
Core Oven	Specially heated chambers for the drying of cores at low temperatures.
Core Sand	Sand for making cores, generally a silica sand, bonded with one or more organic binders that is made into the desired shape and hardened to form a core.
Cross Draft	A current of air that acts to disrupt or change the direction of streams of air before they can enter an exhaust hood.
Crucible	A vessel or pot made of a refractory such as graphite or silicon carbide with a high melting point and used for melting metals.
Cupola	A vertical, cylindrical furnace usually lined with refractories, for melting metal in direct contact with coke by forcing air under pressure through openings (tuyeres) near its base.
Cupola, Hot Blast	A cupola supplied with a preheated air blast.
Cupola Stack	The overall top column of the cupola from the charging floor to the spark arrestor.
Cyclone	A device with a control descending vortex created to spiral objectionable gases and dusts to the bottom of a collector cone for the purpose of collecting particulate matter from process gases.
Cyclonic Scrubber	Radial liquid (usually water) sprays introduced into cyclones to facilitate collection of particulates.
Desulfurizing	The removal of sulfur from molten metal by the addition of suitable compounds.
Direct Arc Furnace	An electric arc furnace in which the metal being melted is one of the poles.
Direct Shell Evaluation	See Fourth Hole Ventilation.
Downdraft Hood	An exterior hood in which the exhaust enters in a downward manner.

Drag	- The lower or bottom section of the mold, flask, or pattern.
Ductile (or nodular) Iron	- Ferrous metal in which the graphite is present in spheroidal shape. The graphite in this shape does not greatly affect the inherent ductility of the metal matrix. Also called nodular iron or spheroidal-graphite iron.
Duplexing	- A method of producing molten metal of desired analysis. The metal being melted in one furnace and refined in a second.
Dust Loading	- The concentration of dust in the gas entering or leaving a collector.
Electric Arc Furnace (EAF)	- The direct arc electric furnace consists of a refractory lined, cup shaped, steel shell with a refractory lined roof through which three graphite or carbon electrodes are inserted. The shell is arranged for tilting to discharge the molten metal.
Electric Induction Furnace (EIF)	- The induction furnace is a cup or drum shaped vessel that converts electrical energy into heat to melt the charge. No electrodes are used in EIF. The induction furnace converts electrical energy into heat by utilizing the transformer principle in which a magnetic field is set up when the primary coil of the transformer is energized. The magnetic field at a high flux density induces eddy currents in the charge which are converted to heat by the electrical resistance of the charge itself.
Enclosing Hoods	- A local exhaust hood where the generation point for air contaminants is within the confines of the hood.
Endothermic Reaction	- Designating, or pertaining to a reaction which occurs with the absorption of heat from the surroundings.
Equivalent Opacity	- The determination of smoke density by comparing the apparent density of smoke as it issues from a stack with a Ringelmann Chart.
Exothermic Reaction	- Chemical reaction involving the liberation of heat, such as burning of fuel.
External Hood	- A hood that does not confine the process or equipment emitting contaminants; functions by inducing a flow of air from the source or release toward the hood opening.

Fabric Filter - A particulate control device using filters made of synthetic, natural, or glass fibers within a large chamber for removing solid particulate matter from the air or gas stream.

Face (of a hood) - An opening through which air flows into the hood.

Facing Sand - Specially prepared molding sand mixture used in the mold adjacent to the pattern to produce a smooth casting surface.

Flask - Metal or wood frame without top or a fixed bottom, used to retain the sand in which a mold was formed; usually consists of two parts, cope and drag.

Fluxing agent - Material or mixture of materials, limestone, dolomite, fluorspar, calcium carbonate which causes other compounds with which it comes in contact to fuse at a temperature lower than their normal fusion temperatures.

Forehearth - Brick-lined reservoirs in front of and connected to the cupola or other melting furnaces for receiving and holding the melted metal.

Foundry Effluent - Waste material in water or air that is discharged from a foundry.

Foundry Returns - Cast iron scrap, gates, risers, and scrap castings, used as one of the raw materials for the production of cast iron.

Fourth Hole Ventilation (Direct Shell Evacuation) - In regard to air pollution control, the using of a fourth hole in the roof of an electric furnace to exhaust fumes.

Fugitive Emissions, Total - All particles from either open dust or process fugitive sources as measured immediately adjacent to the source.

Fugitive Emissions - Emissions not orginating from a stack, duct, or flue.

Full Anneal - A heating-and-cooling process applied to either gray or ductile iron castings to reduce the hardness, improve the ductility, and relieve residual stresses.

Fume - Fine, solid particles dispersed in air or gases and formed by condensation, sublimation, or chemical reaction.

Gate	- The end of the runner in a mold through which molten metal enters the mold cavity.
General Ventilation	- Dilution method of ventilation achieved by reducing pollutant concentrations and by supplying fresh, tempered air.
Graphitizing Anneal	- A heating-and-cooling process that serves to transform, wholly or in part, the combined carbon in cast iron to graphitic or free carbon.
Gray Iron	- Ferrous metal that contains a relatively large portion of its carbon in the form of flake graphite, and substantially all of the remainder of the carbon in the form of eutectoid carbide. Such metal has a gray fracture. These irons have very little ductility.
Green Sand	- A naturally bonded sand or a compounded molding sand mixture which has been tempered with water and additives for use while still in a damp or wet condition.
Griffin System	- A method operating in two stages, to recoup and preheat air by using the latent heat of cupola gases.
Hawley Close Capture Hooding System	- A commercially patented close-capture hooding system for electric arc and electric induction furnaces which control emissions during charging, melting, slagging, and tapping operations.
Heel	- Metal left in ladle after pouring has been completed. Metal kept in induction furnaces during standby periods.
Holding Furnace	- A furnace for maintaining molten metal, from a larger melting furnace, at a proper casting temperature.
Hood	- Projecting cover above a furnace or other equipment for purpose of collecting smoke, fume, or dust.
Hood Leakage (or Loss)	- Emissions which are carried by air currents past the capture zone of a hood.
Hot Blast	- Blast air which has been heated prior to entering into the combustion reaction of a cupola.
Hot Box Cores	- Hot box resins include furan and phenolic resins. The liquid resin is mixed with the core sand and formed in conventional equipment and heated in core boxes.

Indirect Arc Furnace	- An electric arc furnace in which the metal bath is not one of the poles of the arc.
Indraft Velocity	- Linear flowrate of contaminated air through the face opening of a hood.
Induction Furnace	- A melting furnace which utilizes the heat generated by electrical induction to melt a metal charge.
Inlet Volume	- The quantity of gas entering a collector from the system it serves.
Inoculant	- Any of a number of materials usually magnesium that modify the microstructure of cast irons when small amounts are added to the molten metal just before pouring.
Inoculation	- The addition to molten metal substances designed to form nuclei for crystallization.
Ladle	- Metal receptacle lined with refractory for handling molten metal. Ladles are used for iron inoculation, transport, and pouring metal into molds.
Ladle Addition	- The addition of alloying elements to the molten metal in the ladle.
Latent Heat	- Thermal energy absorbed or released when a substance changes state, such as from solid to liquid or from one solid phase to another.
Lining	- Inside refractory layer of firebrick, clay, sand or other material in a furnace or ladle.
Magnesium Treatment	- The addition of magnesium to molten metal to form nodular iron.
Malleable Iron (sometimes called white)	- Ferrous metal obtained by heat treatment of white cast iron which converts substantially all of the combined carbon into nodules of graphite.
Melting Rate	- The tonnage of metal melted per unit of time.
Mold	- The form, generally made of silica sand, which contains the cavity into which molten iron is poured to produce a casting of the desired shape.
Muller	- A type of foundry sand mixing machine.

No Bake Molding	- A core making molding process where no bake resins (polymers) are catalyzed while mixing with sand and harden over a relatively short period of time but sufficiently long to enable the sand to be packed into a pattern to make a mold.
Nodular Iron	- (See Ductile Iron)
Normalizing	- Gray or ductile iron is normalized by heating to 885° to 927°C and cooling in still air.
Off Gas	- Gas emitted from an industrial operation, including the forced ventilation of an area or operation.
Oven Bake Cores	- Oven baked core resins are one of four types: oleoresinous, urea-formaldehyde, phenol formaldehyde, cereal. The resin and core sand are mixed and formed in a pattern. The cores are then baked in an oven for curing.
Oxidizing Atmosphere	- An atmosphere resulting from the combustion of fuels in an atmosphere where excess oxygen is present, and with no unburned fuel lost in the products of combustion.
Oxidation Losses	- Reduction in the amount of metal or alloy through oxidation. Such losses usually are the largest factor in melting loss.
Oxygen Lancing	- It is a process of injecting oxygen with the help of long steel pipe or tube usually covered with refractory. It is used mainly for adjusting of the chemistry of the steel, but may also be used for speeding up of the melting process and for superheating the bath.
Parting Compound	- A material dusted, brushed or sprayed on patterns or mold halves to prevent adherence of sand and to promote easy separation of cope and drag parting surfaces when cope is lifted from drag.
Pattern	- A form made of wood, metal, or other material around which molding material is placed to make a mold for casting metals.
Pig Iron	- The crude iron product of a blast furnace that is produced by the reduction of iron ore and is cast into small bars (pigs); often used as a raw material for the production of cast iron.

Pit Molding	- Molding process for large castings in which lower portions of mold are made in a suitable pit or excavation in foundry floor.
Plume	- A visible, elongated column of mixed gases, partially condensed vapors, gas-born particulates, and smoke emitted from a stack.
Polynuclear Aromatic Hydrocarbons (PAH)	- Hydrocarbons with fused-ring systems, with or without aliphatic side chains.
Pour-Over Inoculation Method	- In this technique of inoculation, hot metal is poured over to an empty laddle containing inoculant.
Preheater	- A device used to preheat the charge before it is charged into a furnace. It is used primarily with induction furnaces.
Push-Pull Ventilation	- Local exhaust control where a receiving hood induces a flow of air toward it while a "push" toward the hood is achieved by mechanical means or prevailing ventilation patterns. Also called blow and exhaust systems.
Recuperator	- Equipment for transferring heat from hot gases for the preheating of incoming fuel or air for hot blast cupolas.
Reducing Atmosphere	- An atmosphere resulting from the incomplete combustion of fuels.
Refractory	- Heat resistant material, usually nonmetallic and used for furnace linings.
Reverbatory Furnace	- A large quantity furnace with a vaulted ceiling that reflects flame and heat toward the hearth or the surface of the charge to be melted.
Riser	- A reservoir of molten metal connected to a casting to provide feeding of additional metal to the casting as it contracts during solidification.
Rotary Furnace	- A furnace using pulverized coal, gas, or oil; of cylindrical shape with conical ends mounted so as to be tipped at either end to facilitate charging, pouring, and slagging.
Runner	- A channel through which molten metal flows from the downgate (sprue) of a mold into the casting cavity or from the casting cavity to the riser.

Sandwich Inoculation Method	In this method of inoculation, inoculant is covered with 1 to 2% steel punching or plate or ferrosilicon. Hot metal is poured over. This allows more hot metal to be poured before the reaction starts and results in greater magnesium recovery.
SCFM	Standard Cubic Feet per minute. The volume of gas measured at standard conditions, usually one atmosphere of pressure and 70°F.
Schumacher System	In this patented sand handling system, an oversized muller is used to produce excess moist sand. This moist sand is mixed with the dry sand leaving the shakeout hopper to reduce dust emissions during spent sand handling.
Sea Coal	Pulverized, high-volatile, bituminous coal frequently added to green molding sand for making molds for the production of iron castings.
Shakeout	The operation of removing castings from a sand mold.
Shell Molding	A process for forming a mold from thermosetting resin bonded sand mixtures brought in contact with preheated metal patterns, resulting in a firm shell with a cavity corresponding to the outline of the pattern.
Shotblasting	Casting cleaning process employing a metal abrasive propelled by centrifugal force.
Side Draft Hood	A receiving hood into which exhaust enters laterally.
Slag	Nonmetallic covering which forms on the molten metal as a result of the flux action in combining impurities contained in the original charge.
Spark Arrestor	Device over the top of the cupola to prevent the emission of sparks.
Sprue	The channel, usually vertical, connecting the pouring basin with the runner to the mold cavity.
Standard Air	Air with a density of 0.075 pounds per cubic foot, generally equivalent to dry air at 70°F and 14.7 psi.
Storage Pile Activities	Load-in, vehicular traffic around storage piles, wind erosion from storage piles, and load-out.

Superheating	- Heating of a metal to temperatures above the melting point of the metal to obtain more complete refining or greater fluidity.
Tapping	- Removing molten metal from the melting furnace by opening the tap hole and allowing the metal to run into a ladle.
Thermal Draft	- Air currents set in vertical motion by heat.
Threshold Limit Value (TLV)	- A concentration in air or an exposure or dose rate felt to be safe for repeated exposure to workers. A set point for control of a hazard.
Tramp Metal	- A metallic element present as an impurity, usually in insignificant amounts.
Tuyere	- The nozzle openings in the cupola shell and refractory lining through which the air blast is forced.
Wet Cap	- A device installed on a cupola stack that collects emission by forcing them through a curtain of water. The device requires no exhaust fan but depends upon the velocity pressure of the effluent gases.
Wet Scrubber	- An air pollution control device, a liquid spray device, usually water for collecting pollutants in escaping foundry gases.
Wind Box	- The chamber surrounding a cupola through which air is conducted under pressure to the tuyeres.

APPENDIX B

CHECKLIST FORMS FOR VARIOUS PROCESS CONTROL EQUIPMENT SYSTEMS IN FOUNDRY

COVER SHEET FOR CONTROL EQUIPMENT CHECKLIST

Facility Name: ______________________ Inspection Date and Time: ______________

Facility Address: ____________________ Inspector Initials: __________________

Facility Contact: __________ ______________________ Phone No.: ______________

Name Title

Type of Process (check)
- ☐ Charge Preparation area
- ☐ Cupola
- ☐ Electric Arc Furnace
- ☐ Electric Induction Furnace
- ☐ Other (describe)

____

____

Type of Control Equipment (check)
- ☐ Fabric Filter
- ☐ High Energy Scrubber System
- ☐ Low Energy Scrubber System
- ☐ Gas Cooling System
- ☐ Local Exhaust System
- ☐ Mechanical Collector; (circle one) Cyclone, Multiclone, Setting Chamber

Process Equipment ID No. ____________________ Control Equipment ID No. ______________

. Is the process system operating? Yes ____ No____ Is the Control System operating? Yes____ No____ (This can often be confirmed by noticing vibration of equipment or fan noise).

. If control system or process(es) is not operating, then conclude the inspection after finding out the reasons.

. Check exhaust stack of the control equipment for any visible emissions (VE)

Note percent opacity ___________ Color ___________ (Take VE readings if in violation of opacity regulations; follow your agency's procedures).

I. CHECKLIST FOR CHARGE PREPARATION

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Total charge (Ton/hr)	Plant records	Preinspection meeting	Compare these numbers with numbers in agency files.	
Coke (lb/hr)	Same as above	Same as above	Same as above (for Cupola only)	
Flux (lb/hr)	Same as above	Same as above	Same as above (for Cupola only)	
Scrap composition	Plant records in plant official's office	Preinspection, before starting plant walk-through	Company should have daily records of raw materials usage.	
Percent steel scrap	Same as above	Same as above	Same as above	
Scrap-appearance (Amount of oil, rust, fine matter, sand, moisture)	Scrap pile or at charge floor	During plant walk through		
Any charge preparation (describe screening, sizing cutting, and reheating)	Near materials storage area or charge floor.	During inspection		
Raw material storage covered or outdoor	Same as above	Same as above		
Charge loading method	Charge floor	During charging operation		
Fugitive emissions	Same as above	Same as above	Describe	
How charges are weighed	Same as above	Same as above	If approximate, describe.	

II. CHECKLIST FOR CUPOLA-HIGH ENERGY WET SCRUBBER

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Monitoring instruments	Instrument panel or at various locations on the system.	Same as above	Request plant official to show you scrubber system instrument panel.	
Calibration of monitoring equipment			Find out last time instruments were calibrated	
Note following data if available: (scrubber)	Instrument panel or instruments located at various locations on system	Same as above	Note this information if available. If instruments are not operating, find out why and for how long.	
Pressure drop across scrubber (in. of H_2O).				
Scrubber liquid flow rate (gpm)				
Scrubbing liquid pressure (psi)				
Inlet Temperature (°F)				
Pressure drop across mist eliminator (in. of H_2O).				
Makeup liquid flow rate (gpm)				
Nozzle operating pressure (psi)				
inlet and outlet static pressure of fan system				

(continued)

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Note following data: (Cupola)				
Melting rate (T/hr)	Plant records	Preinspection meeting		
Coke metal ratio	Same as above	Same as above		
Blast rate (acfm)	Cupola control panel	During blasting operation		
Blast temperature (°F)	Same as above	Same as above		
Exhaust gas temperature (°F)	Cupola or control device instrument panel	During melting operation	Note where the temperature is measured	
SCRUBBER SYSTEM Corrosion, leakage scaling	Outside scrubber system Ductwork Fan housing Pumps and valves Demister	While system is operating	Draw diagram of system and show point of point of corrosion on back of this form or describe.	
	Inside scrubber Shell Trays Demister	While system is off	Describe	
Fugitive emissions	Ductwork Control system	While system is operating	Draw diagram and show point of emissions on back of this form.	

(continued)

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Scrubbing liquid spraying system for plugging or insufficient pressure	Spray nozzles	While system is operating.	This can be indicated by poor flow or poor spraying action by observing through portholes, if possible	
Buildup of scrubbing liquid in sump.	Sump (liquid reservoir at bottom of the scrubber vessel).	Same as above	Large amount of liquid buildup will indicate this situation. This can be checked by observing through portholes or open access doors.	
Fan				
Vibration	Around fan housing	While fan system is running	Visual observation	
Audible belt slippage noise	Around fan housing	Same as above	Noise from housing	
Material buildup or caking on fan blades	Fan blades	While fan system is off	Through access door or opening in fan housing	
Stress mark, cracks in fan blades or wheel	Fan blades, fan wheel	Same as above	Same as above	
Open inspection doors, holes, open portholes	Fan system, ductwork	Anytime	Visual observation around control system	

(continued)

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
CUPOLA Emissions leakage	Cupola top Charge door Other places	Same as above		
Charge door kept open or closed during the operation	Charge floor	During charging operation.		
After-burner operating Also note the temperature if available	Fuel gauge on control panel or actual burner flames if accessible	During operation	Not location and configuration of A.B.	
General housekeeping	Around melting operation	During inspection	Describe bad housekeeping practices which will have effect on emissions (e.g., dust laden floor)	
Startup and shutdown practices	Obtain description from plant official.	Obtain information prior to inspection and observe during inspection	Perform this activity if time permits. If shutdown is observed. note blast rate, exhaust rate, and exhaust temperature.	
Control equipment bypassing	Plant records and control panel	During control equipment bypass operation	Note amount of time control equipment bypassed.	

III. CHECKLIST FOR CUPOLA-GAS COOLING SYSTEM - FABRIC FILTER

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Monitoring instruments	Instrument panel or instruments located at various locations on system	While system is operating	Request plant official to show you instrument panel.	
Calibration of monitoring instrument			Find out last time instruments were calibrated.	
Note following data if available: (Gas cooling system)	Instrument panel or instrument located at various locations on the system	While system is operating during external inspection	Note this data if available. If instruments are not operating, find out why and for how long	
Flue gas velocity (rpm) Flue gas inlet temperature. (°F) Flue gas outlet temperature. (°F) Cooling water rate (gpm) Water spray pressure (psi)				
Outlet gas temperature indicator with warning device operational.	Instrument panel	While system is operating	Some facilities might not have this device.	

(continued)

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Note following data if available: (fabric filter)	Instrument panel or instruments located at various locations on the system	While system is operating during external inspection	Note this data if available. If instruments are not operating find out why and for how long.	
Pressure drop across fabric filter (in. of H_2O) Gas inlet temperture (°F) Differential static pressure (in. of H_2O) between clean and dirty side				
Dew point of gases	From plant officials			
Get the following information (Cupola)				
Melting rate (T/hr)	Plant records	Preinspection meeting		
Coke metal ratio	Same as above	Same as above		
Blast rate (acfm)	Cupola control panel	During blasting operation		
Blast temperature (°F)	Same as above	Same as above		
Exhaust gas temperature (°F)	Cupola or control device instrument panel	During melting operation		

(continued)

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Corrosion, holes, wear points	Around cooling system, pumps	During external inspection	If large enough damage from corrosion, you will see fugitive emissions.	
Fugitive emissions	Around cooling system	During external inspection while system is operating	Draw diagram of system and show point of emissions on back of this form.	
Excess scaling	Internal surfaces of cooling system	During internal inspection when system is off	Take safety precautions and get plant official's approval before opening any access doors.	
Plugged or missing nozzles	Inside cooling system	While spray system is operating	This can be checked by looking through open access doors or portholes. If these are not available, you might have to skip this activity.	
FABRIC FILTER				
Corrosion, weld seam gaps, holes, wear points, physical damage	Fabric filter housing near doors Ductwork Hoppers	During external inspection	Draw diagram of system and show point of corrosion on back of this form or describe.	

(continued)

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Fugitive emissions	Around control system and related ductwork	During external inspection when system is operating	Draw diagram of system and show point of emissions on back of this form.	
Damaged or missing seals and proper airtight closing	Around access doors, joints, ductwork	During external inspection; system can be on or off	Take safety precautions and get plant official approval before opening any access doors.	
Proper operation of cleaning cycles		During external inspection while system is operating	See text for further clarification	
Proper operation of solids removal system	Scre conveyors, bottom of hoppers	While system is operating	In some type of FF normal operations will show regular discharge of solids from hopper or collecting equipment.	
Fan vibration	Around fan housing	During external inspection while fan system is running	Visual observation	
Audible belt slippage noise	Around fan housing	Same as above	Noise from housing	
Material buildup or caking on fan blades	Fan blades	While fan system is off	This activity is necessary only if fan is upstream from fan filter.	

(continued)

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Corrosion, abrasion stress mark, cracks in fan blades or fan wheel	Fan blades, fan wheel	While fan system is off	Through access door or opening in fan housing during internal inspection	
Material deposits on bags	Inside fabric filter	During internal inspection of fabric filter when system is off	Consider all safety factors before entering fabric filter or opening access doors.	
Condition of bags Bag tears Oily Bags Dropped bags Burnspot on bags Bag deterioration Improper bag connection Dampness Collar wear Bag tension	Inside fabric filter	During internal inspection of fabric filter when system is off	Consider all safety factors before entering fabric filteror opening access doors.	
Condition of wear plate	Inside fabric filter wear plate is located where exhaust ducts enter fabric filter.	Same as above	Same as above	
Dust buildup, material bridging	Inside the fabric filter hoppers inlet ducts	Same as above	Same as above Also it can be identified by tapping hoppers with pipe or hammer	
Temperature protection device or baghouse bypass system	This system usually is integrated with fabric filter operation.	The system ideally should be checked when fabric filter system is operating.	This system may not be checked due to operational conditions.	

(continued)

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Fabric filter preheater operational		While system is operating or shut down	This activity may be hard to inspect due to physical location of heaters.	
CUPOLA				
Emissions leakage or fugitive emissions	Cupola top Charge door Other places	Same as above		
Charge door kept open or closed during the operation	Charge floor	During charging operation.		
After-burner operating	Fuel gauge on control panel or actual burner flames if accessible	During operation		
General housekeeping	Around melting operation	During inspection	Describe bad housekeeping practices which will have effect on emissions	
Startup and shutdown practices	Obtain description from plant official.	Obtain information prior to inspection and observe during inspection	Perform this activity if time permits. If shutdown is observed. note blast rate, exhaust rate, and exhaust temperature	
Control equipment bypassing	Plant records and control panel	During control equipment bypass operation	Note amount of time control equipment bypassed	

IV. CHECKLIST FOR ELECTRIC ARC FURNACE (EAF) - ELECTRIC INDUCTION FURNACE (EIF) - FABRIC FILTER

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Monitoring instruments	Instrument panel or instrument located at various locations on system	While system is operating	Request plant official to show you control system instrument panel.	
Calibration of monitoring equipment			Find out the last time instruments were calibrated.	
Note following data if available: (Fabric Filter)	Instrument panel or instruments located at various locations on the system	While system is operating during external inspection	Note this data if available. If instruments are not operating find out why and for how long.	
Pressure drop across fabric filter (in. of H_2O) Gas inlet temperature (°F) Differential static pressure (in. of H_2O) between clean and dirty side in compartmontalize FF				
Dew point of gases	From plant officials			

(continued)

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Note following data: (EAF OR EIF)				
Melting rate (lb/hr)	Plant records	Preinspection meeting		
Power rate	Control board	During inspection		
Temperature in furnace (°F)				
Oxygen lancing: Rate (cfm) (EAF only)	Control panel	During lancing operation		
Duration	Same as above	Same as above		
FABRIC FILTER				
Corrosion, weld seam gaps, holes, wear points, physical damage	Fabric filter housing near doors Ductwork Hoppers	During external inspection	Draw diagram of system and show point of corrosion on back of this form or describe.	
Fugitive emissions	Around control system and related ductwork	During external inspection when system is operating	Draw diagram of system and show point of emissions on back of this form.	
Damaged or missing seals and proper air-tight closing	Around access doors, joint in ductwork	During external inspection; system can be on or off	Take safety precautions and get plant official approval before opening any access doors.	

(continued)

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Proper operation of cleaning cycles		During external inspection while system is operating	See text for further clarification	
Proper operation of solids removal system	Screw conveyors, bottom of hoppers	While system is operating	In some type of FF normal operations will show regular discharge of solids from hopper or collecting equipment.	
Fan vibration	Around fan housing	During external inspection while fan system is running	Visual observation	
Audible belt slippage noise	Around fan housing	Same as above	Noise from housing	
Material buildup or caking on fan blades	Fan blades	While fan system is off	This activity is necessary only if fan is upstream from fan filter.	
Stress mark, cracks in fan blades or fan wheel	Fan blades, fan wheel	While fan system is off	Through access door or opening in fan housing during internal inspection	
Material deposits on bags	Inside fabric filter	During internal inspection of fabric filter when system is off	Consider all safety factors before entering fabric filter or opening access doors.	

(continued)

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Condition of bags Bag tears Oily Bags Dropped bags Burnspot on bags Bag deterioration Improper bag connection	Inside fabric filter	During internal inspection of fabric filter when system is off	Consider all safety factors before entering fabric filteror opening access doors.	
Condition of wear plate	Inside fabric filter wear plate is located where exhaust ducts enter fabric filter.	Same as above	Same as above	
Dust buildup, material bridging	Inside the fabric filter hoppers	Same as above	Same as above	
Fabric filter preheater operational		While system is operating or shut down	This activity may be hard to inspect due to physical location of heaters.	
(EAF OR EIF) Visible fugitive emissions during: Charging Tapping Backcharging Melting Oxygen lancing	Around EAF	During furnace inspection	Describe exhaust system and show points of leakage	

(concluded)

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Charge clean and dry (EIF only)	Charging area	During charging operation		
Preheating of buckets or conveyors and Fugitive emissions from them. (EIF only)	Same as above	Same as above		

V. CHECKLIST LOCAL EXHAUST SYSTEM - LOW ENERGY FOR WET SCRUBBERS

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Monitoring instruments	Instrument panel or at various locations on the system.	Same as above	Request plant official to show you scrubber system instrument panel.	
Calibration of monitoring equipment			Find out last time instruments were calibrated	
Note following data if available for scrubber	Instrument panel or instruments located at various locations on system	Same as above	Note this information if available. If instruments are not operating, find out why and for how long.	
Pressure drop across scrubber (in. of H_2O). Scrubber liquid flow rate (gpm)				

(continued)

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
SCRUBBER Corrosion, leakage	Outside scrubber system Ductwork Fan housing Demister	While system is operating	Draw diagram of system and show point of point of corrosion on back of this form or describe.	
	Inside scrubber Shell Trays Demister	While system is off	Describe	
Fugitive emissions	Ductwork Around control system	While system is operating	Draw diagram and show point of emissions on back of this form.	
Scrubbing liquid spraying system for plugging or insufficient pressure	Spray nozzles		While system is operating.	This can be indicated by poor flow or poor spraying action.
Buildup of scrubbing liquid in sump.	Sump (liquid reservoir at bottom of the scrubber vessel).	Same as above	Large amount of liquid buildup will indicate this situation. This can be checked by observing through portholes or open access doors.	
Fan				
Vibration	Around fan housing	While fan system is running	Visual observation	

(continued)

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Audible belt slippage noise	Around fan housing	Same as above	Noise from housing	
Material buildup or caking on fan blades	Fan blades	While fan system is off	Through access door or opening in fan housing	
Stress mark, cracks in fan blades or wheel	Fan blades, fan wheel	Same as above	Same as above	
Open inspection doors, holes, open portholes	Fan system, ductwork	Anytime	Visual observation around control system	
EXHAUST SYSTEM Note the type of hood: Enclosures Receiving hoods Exterior hoods Canopy hoods Movable Hoods				
Fugitive emissions	Around process equipment and hood	While process is operating	Draw diagram of system and show point of emissions on back of this form.	
Exhaust gases drawn adequately into the hood	Same as above	Same as above		
Capture velocities	Around hood	Same as above	Visually observe adequacy of captive velocities; if inadequate, emissions will not be drawn into hood.	

(concluded).

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Location of hood	Around process equipment and hood	Same as above	If visual observation hood is improperly located, exhaust gases will not be captured.	
Cross-drafts or thermal drafts	Same as above	Same as above	If cross- or thermal drafts are present, they will deflect exhaust gases and will not be captured by hood.	
Dust buildup or obstruction in ductwork	Ductwork associated with hoods	Anytime	Conduct this activity only if accessible and safe.	
Flaps being used around canopy hoods	Around process equipment	When process is operating	If flaps are not used properly, some emissions will escape from hood.	

VI. CHECKLIST FOR LOCAL EXHAUST SYSTEM-MECHANICAL COLLECTORS

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
MECHANICAL COLLECTORS				
Corrosion, holes, wear points	Main shell of collector Ductwork Hoppers	During external inspection	Draw diagram of system and show point of corrosion on back of this form or describe.	
	Inside walls of shell and hoppers Gas outlet tube Skimmer plate	While system is off, during internal inspection of the equipment.	In some cases you will not be able to do this activity because of inaccessibility to area.	
Solids removal systems for proper operation	Solids removal system such as screw conveyor, settling chamber	While system is operating	If system is operating correctly you will see solids removal from control equipment also.	
Dust buildup and plugging or foreign matter restriction	Inside walls of the collector Dust outlet Ductwork	While system is off	This can be checked through access door, portholes. In some cases you will not be able to do this because of inaccessibility to area.	
Proper operation,. air leakage and wear	Flop gates or internal vanes Gravity valve Rotary air lock Seal between hoppers and cyclone Body of collector	During external inspection while system is running or during internal inspection while system is off		

(continued)

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
LOCAL EXHAUST SYSTEM Note the type of hood: Enclosures Receiving hoods Exterior hoods Canopy hoods Movable hoods				
Fugitive emissions	Around process equipment and hood	While process is operating	Draw diagram of system and show point of emissions on back of this form.	
Exhaust gases drawn adequately into the hood	Same as above	Same as above		
Capture velocities	Around hood	Same as above	Visually observe adequacy of captive velocities; if inadequate, emissions will not be drawn into hood.	
Location of hood	Around process equipment and hood	Same as above	If visual observation hood is improperly located, exhaust gases will not be captured.	
Cross-drafts or thermal drafts	Same as above	Same as above	If cross- or thermal drafts are present, they will deflect exhaust gases and will not be captured by hood.	

(concluded)

What To Look For	Where To Look	When To Look	Additional Comments (How)	Observations (Your Comments)
Dust buildup or obstruction in ductworks	Ductwork associated with hoods	Anytime	Conduct this activity only if accessible and safe through access doors or portholes.	
Flaps being used around canopy hoods	Around process equipment	When process is operating	If flaps are not used properly, some emissions will escape from hood.	